NATIONAL SCIENCE FOUNDATION AUTHORIZATION

HEARING

BEFORE THE

SUBCOMMITTEE ON
SCIENCE, TECHNOLOGY, AND SPACE

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SCIENCE, AND TRANSPORTATION
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NATIONAL SCIENCE FOUNDATION AUTHORIZATION

MONDAY, APRIL 19, 1982

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE,
Washington, D.C.

The subcommittee met, pursuant to notice, at 9:40 a.m., in room 235, Russell Senate Office Building, Hon. Harrison Schmitt (chairman of the subcommittee) presiding.

Staff members assigned to these hearings: Dennis W. Barnes, professional staff member, and Steven H. Flajser, minority professional staff member.

OPENING STATEMENT BY SENATOR SCHMITT

Senator SCHMITT. This morning's hearing will come to order. I want to welcome all of you to the second day of hearings before the Subcommittee on Science, Technology, and Space dealing with the fiscal year 1983 authorization request for the National Science Foundation.

On March 25 we heard from Dr. John Slaughter, the Director of the Foundation, and Dr. Donald Langenberg, the Deputy Director of the Foundation. Dr. Lewis Branscomb, Chairman of the National Science Board, submitted testimony, but was prevented by weather from appearing in person.

We have heard a great deal about the Foundation's plans for fiscal year 1983 and explored a number of problems to which this Nation must find solutions if we expect to continue enjoying the advantages and security which have resulted from our critical edge in science and technology. We not only must improve what we are doing, but we also must recognize the role that science and technology, and in particular science and technology education, have played in our past and will again play in our future.

Today we will hear testimony from outside witnesses on a number of these problems:

One, our woefully inadequate national performance in educating and training our young men and women to live and work in this, the most technologically advanced society in the world;

Two, the technological obsolescence of the instrumentation with which academic basic research and education are conducted; and

Three, reductions in the extent of research which is conducted under the NSF sponsorship.

Let me give you some indication of the problems that are of concern to the subcommittee:

The number of NSF awards estimated for fiscal year 1983 is about 12,000, compared to 14,500 in fiscal year 1981, and this in the face of everyone saying that there is not nearly enough undergraduate and particularly graduate work being done in science and engineering;

Two, the number of graduate students supported will be down about 200 from the fiscal year 1981 total of 9,200; and

Three, about $95 million will be available for instrumentation in universities, where the deficiency is estimated at somewhere between $1 and $2 billion.

Thus, while the fiscal year 1983 NSF budget may appear well treated compared to some other civilian programs, NSF's education and research are losing ground at a time when the challenges to our inventiveness and technologies, and indeed our national security and our economic well being, are increasingly aggressive and successful.

Meeting these challenges is a national responsibility that must be shared by industry and business, State and local governments, colleges and universities, professional societies and the Federal Government. The Federal involvement is essential, but it ought not to be preemptive, as it tended to be in recent times.

Industry and business particularly are going to have to provide a greater share of the national investment resources for basic research and science and engineering education, from which will result the knowledge and manpower pools on which their future success depends. The investment by industry in replenishing the human resource base that they utilize must be comparable to the investment that they would place in any kind of inanimate resource base.

I am pleased to note increasing evidence of acceptance of responsibility of this nature by the private sector. Recently, as examples:

First, a research cooperative has been developed by the Semiconductor Industry Association to funnel several million dollars a year from private companies into basic semiconductor research at U.S. universities;

Second, a joint university-industry council for chemical research, currently including about 130 university and 30 corporate members, is working on a formula for continued private funding, which will be based partly on the number of graduates hired by the corporate participants;

Third, two major microcomputer manufacturers have offered to donate a significant number of computers to the NSF for use in high school and introductory college education in science and engineering; and

Fourth, we have the commitment by the Exxon Corp. to, I believe, $15 million annually to university science and engineering research and student assistance.

At our March 25 hearing, I raised with Dr. Slaughter the possibility of making some of the NSF awards contingent on matching funds from business or industry. Such an initiative could be an efficient way of acceptance by the Federal Government and the private sector of their shared concern for the vitality and improvement of our academic research and education enterprises, and also would provide a mutual means of leverage with both Federal and private funds.

I would like to explore this idea further today with our witnesses in the course of our questioning. We appreciate having all of our witnesses with us and look forward to their testimony.

And I am happy also to be joined by my distinguished colleague from Washington, Mr. Gorton. Do you have a statement?

Senator GORTON. No.

Senator SCHMITT. Our first witness, then, is Ms. Sarah Klein, president of the National Science Teachers Association, who is an eighth grade science teacher from Roton Middle School in Norwalk, Conn. She is accompanied by Mr. Bill Aldridge, executive director of the association, from Washington, D.C.; and Mrs. Mary Beavis, a high school physical science teacher, Rio Grande High School in Albuquerque, N. Mex.

It is a delight to have the three of you with us, and if you wish to summarize your testimony, Ms. Klein, and allow any supplemental comments by your distinguished colleagues, that will certainly be acceptable, and we will go then to questions on completion of the summary.

STATEMENT OF SARAH E. KLEIN, PRESIDENT, NATIONAL SCIENCE TEACHERS ASSOCIATION, EIGHTH GRADE SCIENCE TEACHER, ROTON MIDDLE SCHOOL, NORWALK, CONN., ACCOMPANIED BY BILL G. ALDRIDGE, EXECUTIVE DIRECTOR, NSTA, WASHINGTON, D.C.; AND MARY BEAVIS, HIGH SCHOOL PHYSICAL SCIENCE TEACHER, RIO GRANDE HIGH SCHOOL, ALBUQUERQUE, N. MEX.

Ms. KLEIN. Thank you very much. Good morning, Senator Schmitt. I certainly want to thank you and the committee members for the opportunity to testify in regard to the crisis in science education and authorizations for science education in the NSF budget.

We feel that we do have a specific case to literally spew out this year. We have written testimony to submit for the record, but I would like to speak informally this morning in review of the testimony that will be presented.

Senator SCHMITT. You may do so, and your entire written testimony will be included in the record, without objection.

Ms. KLEIN. Thank you very much.

As an eighth grade general science teacher, I feel tremendous responsibilities and feel that I must speak on behalf of all science teachers. The majority of these science teachers have been involved with NSF programs in the past with regard to either an academic year institute, a summer institute, a sequential program in curriculum and development, or specific workshops.

I feel very strongly that we must base the future on the past. We have had tremendously successful results with these teachers in the past. The young teachers, the comparatively new teachers in the field of science education, have not been privileged to attend the numbers of science institutes and all these other programs of

NSF that I have been privileged to attend, as well as many colleagues that are near my age.

We really must admit this dual mission that NSF has—to strengthen not only scientific research but science and engineering education at particularly the precollege level. In presenting testimony this morning, I would like to briefly point out our critical shortages of math, science, and chemistry teachers. I feel that we must include mathematics in this because both mathematics and science are so closely related. In the past 10 years, the number of mathematics teachers prepared has dropped approximately 78 percent; in science, 64 percent.

These shortages are showing up strongly in some of our Western States. Particularly, I would like to mention California, where there is so much going on in the field of electronics, where we really do need to have young people to go into these fields.

I suspect, as an eighth grade general science teacher I am well aware of the students that are interested in science, the ones that do go into science and the ones that will continue in science. And the thing that really must be done is to find programs to keep teachers in the field of science education, and this is being done or could be done through the National Science Foundation funding.

I realize that the National Science Foundation is asking for a commission to be funded, but while this commission is taking action, we cannot stop. Our young people today are our investment in the future, and the teachers that we have in science today are really the ones that have to prepare the young people for our investment in the future of the United States.

We could go on and compare the United States with other countries, but I feel that that is just really shirking our own responsibilities to our own people. The United States has a well-founded educational system and we, at the Federal level, must admit to this and do something to keep it unified.

We are not asking for a specific unilateral kind of an educational program for all the United States, but we are asking for unified guidelines through the National Science Foundation, to make a more unified way for distributing some educational funds.

Some of the other shortages besides just the shortages in math, chemistry, and physics are in our testimony, and to summarize quickly: Substantial numbers of unqualified persons are teaching science and mathematics in the secondary schools, and I believe that this is one area where one of our recommendations could help, in trying to reduce these unqualified persons. I believe that the publicity that has been given by the media suggests that there are no shortages of teachers. That may be true in some fields, but in the field of science this is not true, and many of the teachers that are going in to teach science are unqualified.

Most certified teachers of math and science at the elementary level and at the secondary level are badly in need of in-service training. We have documented this with statistics showing that in the last 10 years very few science teachers have had updating.

There needs to be new sequences of science and math courses because of the highly technological information that is coming into the classroom today through the computers and robotics.

Elementary science consultants are needed, and I think that if I had to key in on one particular item, I would feel that we need to begin at the beginning. If we start at the elementary level with science consultants and science specialists in the elementary schools, it would not take very long, say, a minimum of 12 years, and all those elementary schools would be strengthened. Now, that would be a longer term approach, but it also would help take care of the short-term problems.

Elementary and secondary schools need access to microcomputers. These are available and perhaps these would be supplied through the private sector. However, I still feel that guidelines need to come from a central source.

Science curricula need revising; teachers need training in new materials and new methods of sequencing content. This was one of the big advantages in previous years, when there was some funding from NSF for a constant—well, more of a sequencing of materials through BSCS programs and chem study.

We can show that $65.5 million can be freed for science education activities.

We also have a recommended plan for how this $65.5 million can be utilized. One of the cries that we have heard all this year is that it is too little for too much. We feel that anything that is given through NSF for funding for helping teachers is not too little and not for too many people. We feel that those that are in the field do need help, they need serious help; they need profound help through NSF funding.

I feel very strongly, too, that the public image of the science teacher has been battered. It has really taken quite a beating. Science itself has become a very popular item through the new glossy—and I use that "glossy" in quotes—magazines and through the highly popularized topics that the magazines choose to inform the public about. But the exciting thing about science is that science is a way of learning, it is a way of making our public literate.

The other thing that I have heard time and time again is that if NSF does fund all of these programs, will there be any reason why teachers will stay in the field of teaching? They may go into the private sector to work.

I maintain that if they do then our Federal Government has also helped to provide a literate science, a scientifically literate community to make wise decisions, to help make us a better country overall. So our country cannot lose, the Federal Government cannot lose, through funding NSF.

We will welcome questions. Thank you very much.

Senator SCHMITT. Well, thank you, Ms. Klein. We appreciate that very much. Your testimony is going to be very useful to us.

You indicated that it is not a coincidence that the decline in science and mathematics teacher graduates indicated in table 2 starts with the Federal Government's retrenchment in the funding of a variety of science and technology programs back in the early 1970's. Isn't that also when a lot of people who were training to be scientists and engineers were thrown into the marketplace without jobs in those areas and many, I understand, went into teaching? Did they in turn say, hey, do not go into science and engineering, look what happened to me?

Ms. KLEIN. I think Bill can answer that better than I could.

Mr. ALDRIDGE. Well, I do not believe that—I think that the period you are describing was largely one associated with a surplus of Ph. D. graduates in physics and chemistry, and some engineering fields. I do not believe any of those really went into secondary school teaching.

Senator SCHMITT. I tell you, I remember that time. I was right in the middle of it. I was hearing all sorts of stories about people going into teaching from teachers who had been displaced by the more highly qualified, in fact they claimed overqualified, people going into teaching.

Mr. ALDRIDGE. Well, this was a period of extremely rapid growth of community colleges, and a very large number of those people entered that market. Where they could not perform research, they could teach at the college level. I think that probably is what absorbed most of them, rather than the secondary schools.

Senator SCHMITT. Well, you are saying that that did not happen, in spite of the stories we were hearing at that time?

Ms. KLEIN. I think that is exactly right. It certainly did not happen in our area and in the New England area.

Senator SCHMITT. But nevertheless, overall there was a pall cast, was there not, on science and engineering as a career during that period of time?

Mr. ALDRIDGE. Yes. But what we are seeing now is a situation where the media over the last 5 years have taken—have provided an image that there is a very great surplus of teachers in all fields. And too, that is supported by some national organization whose major goal is to keep—keep teachers employed regardless of their qualifications.

Our organization is concerned about the professional aspects of teaching, and we feel that there are unqualified—we know in fact by the evidence that there are unqualified teachers being placed in schools in very large numbers.

Senator SCHMITT. Now, what about parental involvement? Do any of the programs you encourage or support bring the parent into science and related activities, mathematics activities in the schools, so that the children have a favorable home environment for learning in these areas?

Ms. KLEIN. We certainly try. With so many parents—with both parents involved in the job market today, it is really very difficult to get parents to become involved with the students. We have found a sharp decline in interest in, say, science fairs, for example, in our own particular school systems.

Senator SCHMITT. Is that right? Because it is just the opposite in New Mexico. We had a threefold increase in participation I think just over last year.

Ms. KLEIN. I think that is really great. Rhode Island has a fabulous science fair program. Massachusetts' has declined. I think the national interest has maybe risen, but from the standpoint of parents becoming involved, not as many parents are encouraging students in the field of science.

Those parents that are involved themselves feel very strongly about it, but the ones—the others are not. Many of them say, well, why should we become involved in science; it is just really ruining our whole country. And you know, those are statements that are off the top of people's heads. They really do not know.

And this is why I feel so strongly that we really must have a more scientifically literate overall view from many parents.

Senator SCHMITT. Has your organization analyzed the NSF programs that came into existence in the sixties, early sixties in particular, for their successes and failures? Or if initially successful, why then did they seem to lose general support?

Mr. ALDRIDGE. Yes; I can respond to that. There is evidence presented in the testimony in regard to some of the new curriculum which came into existence in that period, particularly the early curriculum, the physics curriculum, chemistry, biology curriculum. I think from what we know the problems arose when some of the newer curriculum were broadened into other areas and came under severe criticism, and as a consequence of that criticism the foundation stopped all implementation efforts, failed to prepare teachers to teach the materials, failed to have the money to work closely with teachers or the community to implement the programs.

It is when the implementation stopped that the whole thing just died, and then the support, of course, was taken away at the same time.

Senator SCHMITT. We have heard—I will yield in a moment to my colleague from Washington. But we have heard that the blame is not entirely on the NSF for getting cold feet, but within the teaching profession itself. The teachers that went to the various science fairs, who went to the various workshops, turned out to be the same teachers year after year after year, and there was not even an outreach within the teaching profession to see that there was a broadening of activities. Is that a fair criticism?

Ms. BEAVIS. May I speak to that? I really do not feel that is a fair criticism. The teachers that went to the NSF workshops, the inservices, were those who were very interested in the field that they were teaching, and I am thinking of physics in particular, who had a chance to spend the summer away, who came back and spread the gospel, if you will.

And the following year several other teachers would go. It was not always the same person who went. It was spread out, I believe.

Mr. ALDRIDGE. When you spend $100 million, you can saturate the market. But that saturation has long since passed. It is true, what you are saying is true, there were people who simply exploited the institutes. There were situations that arose where they were not put to the best use. But that is no longer true. It has not been true for years.

Ms. KLEIN. One other comment that I think needs to be put into the record, and that is with regard to the curriculum at that particular time it was developed. We do have statistics to show that the traditional types of programs were compared with the developed programs by NSF, and upon testing the students tested higher with the NSF-developed programs than they did with the traditional programs.

And by the same token, the minorities scored higher on the NSF-developed programs than did—than they did on the traditional type programs. So I just feel that we must not disregard those curriculums that were continually updated and revised, so that they were an ongoing, well-documented, well-funded curriculums. That was both in—well, in all three fields: Physics, chemistry, and the biological studies.

Senator SCHMITT. If only slightly over half of those who do graduate in fact in mathematics go on to teach, where do the remainder find employment?

Mr. ALDRIDGE. These are people who have been prepared to work in fields involving computing and in engineering fields. A person who is trained as a physics teacher who has had sufficient background in physics, mathematics, and computer science is fully qualified to enter a position at a salary which is roughly twice what he can enter as a teacher, and that is what is happening to them.

Senator SCHMITT. Ms. Klein, you indicated almost five times more science than math teachers left teaching last year for employment in nonteaching jobs than left due to retirement. What kind of employment did they accept and what were their reasons for leaving teaching?

Ms. KLEIN. The same thing exactly.

Senator GORTON. Well, in light of these current shortages, how are those States which are considering increasing graduation requirements for science and mathematics going to do so?

Mr. ALDRIDGE. They are going to do it by placing unqualified teachers in the schools. The fact that California employs—84 percent of the newly employed teachers in California last year were unqualified. They are going to do this across the board. They are going to reduce certification requirements. They are going to employ people who are marginally qualified or unqualified, unless something is done to prepare those people.

It is—it is really a catastrophic situation.

Senator SCHMITT. How do you measure qualification?

Mr. ALDRIDGE. We have recently conducted a survey of certification among the 50 States. When we say qualified, we are talking about subject matter qualification. We are not talking about whether they have had education courses or something like that. We are talking about having had a course or two in science and therefore being qualified to teach.

It is a situation of that kind. We are asking the principal, is this person—does he have adequate background, or she, to teach that class? And we are letting their judgment in terms of credit hours in the field determine whether they are qualified or not.

Ms. KLEIN. I think I can give you a case in point with regard to mathematics, maybe, that strikes home maybe a little closer than science. But our daughter has a masters in art and was teaching art at the elementary level. She was relieved of her position because they removed all art from the elementary school system in which she was teaching—this was in Michigan—and told that she would be reassigned.

She felt that that was really great. She would be glad to teach art at any level, because she taught it at the college outside of school, workshops and so forth. When she got her assignment, she was assigned seventh grade mathematics, seventh grade reading, and eighth grade social studies with emphasis on law.

And I have heard other cases in point, but this one I think really was brought home much more closely than any of the others. I know that science teachers have been doing the same thing.

Senator SCHMITT. Are assignments then on the basis of seniority now, rather than on the basis of qualification?

Ms. BEAVIS. It differs, I believe, from State to State, if they have a RIF policy in action. Some of these are based on seniority, some are based on qualifications, some of them are based on program needs.

Senator SCHMITT. Well, in some colleges and universities we are seeing a movement toward increased admission requirements for science and math. Is that going to tend to make the situation worse, by decreasing the pool of people available for college instruction?

Mr. ALDRIDGE. Well, it will either make the situation worse or the people will enter with paper qualifications, but in fact will not be qualified. I think what we will see is the schools will offer the courses because they will be required to do so.

The problem is that you will be placing people in those classes who are not qualified. The consequences of that for the colleges and universities are entering freshmen who simply do not have the skills that they need and the knowledge that they need. It is going to present an enormous problem of remediation for the universities and colleges.

Ms. KLEIN. Mr. Aldridge and I attended a workshop in December and heard members from the defense community and military community talk about the problems that they have been having with incoming trainees, and we just feel that—I suspect I listened very carefully, because I felt had we had better support at the elementary level, at the middle school level, junior high school level, some of these young people going into the high schools would be qualified for the thing that they are expecting them to be qualified for in the defense program, in the military programs.

I feel very strongly that the Defense Department does not have to reinvent or recreate our science education wheel, because the mechanism is there. But we need the support.

Senator SCHMITT. Well, one of the little recognized functions of the Department of Defense these days is as the largest vocational education system in the country, including remedial education in a variety of fields.

Mary, you are familiar with the Powdrells in Albuquerque, the greatest barbecue in New Mexico. The Powdrells who are a black family that have a very successful two-restaurant business in Albuquerque, have told me that they are running into the same problem. And I only say this because it is an independent business family who have a very difficult time finding qualified people to employ in their restaurants, in what you would normally think of as a requirement for a simple set of skills.

But they need people who are qualified in math and are reasonably well prepared by the educational system. They were telling me just a few days ago that it is getting increasingly difficult to find those kinds of people.

So the problem is not just in the military. I think the General Electric Corp. testified to the same fact in a previous hearing in

New Mexico. They do have a difficult time finding people who can perform very basic calculation skills in their assembly manufacturing and assembly plant in New Mexico.

The New Mexico School System is not nearly as bad, I believe, as other parts of the country in terms of the science and education skill levels of their high school graduates.

Mary, how many vacancies in science and math are there in New Mexico public schools, both real vacancies and those that are not filled by qualified teachers?

Ms. **Beavis**. According to the survey that was taken through our State department of education and came into NSTA, we are experiencing shortages to adequate, which would mean—about 50 percent would be a critical shortage, I believe it is 60 percent would be a shortage of those positions that are being filled, which means we are losing 40 percent of our people.

I cannot give you an exact number because that at this particular point is now being—this information is being gathered. This is a question that has been asked.

Senator **Schmitt**. Do you know how this compares with other States?

Ms. **Beavis**. Yes. According to the testimony—let me see. I believe—Bill, if you can help me out.

Mr. **Aldridge**. Just slightly below the average, I believe, for the Nation. The worst situations are the Pacific States. The best situation is in the Northeastern States, where of course they have such an enormous decline in the secondary school population that they do not have a problem of seeking new teachers.

Ms. **Beavis**. The figures we have here are like 43 percent.

Senator **Schmitt**. Is there any portion of New Mexico where shortages are more pronounced than others?

Ms. **Beavis**. Certainly. In the small rural areas there are more shortages. People there are required to teach many, many subjects, because of the numbers of students, the numbers of teachers that are available. We do have some shortage in physics and some shortage in chemistry in the Albuquerque area.

Mr. **Aldridge**. Senator, that generally is true. We did some spot analysis of the responses, and the smaller schools and the rural schools tended to be the ones reporting the greatest shortages and the urban suburban schools tended to report percentagewise a smaller number.

Senator **Schmitt**. We are finding, however, that the qualifications of young people applying to the service academies from New Mexico seem to be fairly uniform throughout the State. I will have to go back and verify that. That would be a good thing for us to look at for the record as just one case in point.

The top students at least are apparently of similar quality and background all over the State. There are exceptions, of course. There are certain school systems like the Los Alamos School System that have an exceptional situation with regard to science, engineering, and mathematics education. But overall, it appears that there is access if the student is motivated to get the education that they need.

I should add as a footnote that in the last 2 years we have seen a doubling of the number of applicants for service academies, and that the quality is quite high within that very select group of people.

Ms. **Beavis**. One thing, I think, speaking to the teaching that is going on in the areas, it is very good. But one thing is that we—and I think this is brought out in the testimony, the numbers of teachers that we have who are leaving the field. They are leaving the field. They have been there a long time. There are no teachers to come up and take our places, and this is of extreme concern because they—students—have been getting good training. What is going to happen in the future?

Senator **Schmitt**. Yes. Mary, do you know what the minimum certification requirement to teach science or math in secondary school systems is?

Ms. **Beavis**. In science—I am not really certain about math. I would rather speak to the science because I am fairly certain about that.

At the elementary level, the state requirements for certification are only 3 hours of science. Now, each university, of course, can set their own standards, but to me, the State standards, that is what they have to meet. I believe the University of New Mexico——

Senator **Schmitt**. Three hours of a course passed?

Ms. **Beavis**. Of a course passed, right.

Senator **Schmitt**. But no——

Ms. **Beavis**. This includes some methodology as to how to teach science.

Senator **Schmitt**. Yes, but there is no level of proficiency required to be certified?

Ms. **Beavis**. Well, if you have a failing grade, I don't guess you get——

Senator **Schmitt**. I said passing grade. But beyond that?

Ms. **Beavis**. No. At the secondary level there are three plans—by secondary level, I mean grades 7 through 12. There are three plans that are necessary or that you can apply for. In math I believe it is 54 hours of credit, plus your professional education courses and so on.

Another plan is 24 hours in each of two fields such as 24 hours in chemistry, 24 hours in physics. And then there is a third plan which is a composite plan. The second plan is really the one that most high school teachers fall under. However, the math teachers usually fall under the first plan which is 54 hours of credit in that particular academic field.

Senator **Schmitt**. Is this very typical nationally?

Mr. **Aldridge**. Yes. There are quite a number of States that have a broad form of certification which allows a teacher to be prepared to teach any science by simply having a distribution of credits.

Senator **Schmitt**. New Mexico may be a slightly unusual environment because we find in our political surveying that the level of sophistication relative to science and engineering in the population as a whole is fairly high compared to the national averages. And one might understand that with the major laboratory systems and defense installations, as well as an increasing amount of engineering-based industry in the State.

And with our history—as a matter of fact, the recent landing of the Space Shuttle at the White Sands Missile Range has apparently sparked at least initially a significant upswing in science interest on the part of students. A number of teachers already have told me, and principals have told me, that they do not know quite how they are going to handle it, for the very reasons that you say.

There is a shortage of people and all of us hope the kids are interested. And I may have unwittingly contributed to that by seeing that the student body presidents of all the high schools were invited and did, in fact, attend the launch.

So that was my motivation, but I am afraid I put an additional burden on the school systems that I did not think about when I made that invitation. I do not mind having put that burden on them. Maybe it will have some secondary effect.

Mr. **Aldridge**. You know, Senator, the National Science Teachers Association is the contractor for the Space Shuttle student involvement project. And we had one of our student winners, Todd Nelson, with an experiment onboard that last Shuttle, and the director of that project is here in the hearing room today.

Senator **Schmitt**. Well, good.

Mr. **Aldridge**. Dorothy Culbert.

Senator **Schmitt**. Dorothy Culbert, is it?

Mr. **Aldridge**. Yes.

Senator **Schmitt**. Congratulations. Keep up the good work. It is a great program, one I have pushed for years. I am glad it is finally starting to—I was going to say bear fruit, but I guess it is bearing insects right now.

Well, that kind of stimulation obviously is the horse that may pull the cart. It did once before, and let's hope it does again, although in the transition it is going to be difficult. There is going to be inadequate assistance.

The other thing, do you all have any ideas on how we can get industry to support the movement of qualified teachers into the elementary and secondary school system? Because part of your problem is that they are hiring away the best baccalaureate degree holders out of that stream, as well as out of the graduate education stream.

Mr. **Aldridge**. Well, we——

Ms. **Klein**. I am going to let Bill answer those questions. We sponsored a business, industry, and science education seminar last summer and had several interesting things come from that, and Bill has been in much closer contact with the business and industry than either Mary or I have. So I am going to let Bill field that question.

Mr. **Aldridge**. Well, the problem of interesting business and industry at the precollege level is a very difficult one, as you might guess. It is ironic that the Federal Government provides enormous support for vocational education, which is much more closely related to business and industry, and one would expect should be an industry responsibility. And yet, in the area of science education, which is less directly relevant to industry, there is a great deal of expectation that we should try to get support there.

We are trying very hard but with no success, or very little success. We do have some ideas, however. We believe that, for example, if we could have a cooperative arrangement between industry and education where teachers of science and mathematics could be employed during the summer so that they could learn about recent applications in their field, this would have the advantage of enhancing their salaries at the same time that it provided them relevant experience for teaching.

So there are a variety of different kinds of arrangements one could enter. But we find, frankly, little interest on the part of business and industry in specific proposals of that kind. And I think part of that has to do with the very severe economic situation that they are facing, and the crises in engineering faculty and engineering manpower.

Senator SCHMITT. That is an excellent thought. I was sorry to be listening only with one ear, but we try not to let these good ideas pass us by.

Is it impossible to imagine that a public school system would pay teachers differentially based on the skills required for teaching, rather than just on seniority?

Mr. ALDRIDGE. It is being done in Houston, and I believe in Memphis now. The problem that you encounter is what you are saying then is that there is something qualitatively better about a person teaching math or science than perhaps English. As a scientist, I regard English as just as important and I regard art just as important, and it is difficult for me to believe that we can use the law of supply and demand in those circumstances.

On the other side of that, or as another point, if you go into a union situation, it is absolutely impossible, and a good bit of the country has teachers' unions or organizations which are the equivalent. And you simply cannot get that through.

Senator SCHMITT. Well, if industry were to provide, or if we were able to come up with some means of encouraging business and industry to provide summer employment for teachers of science and mathematics, that would increase their skill level as well as increase the monetary awards for activity in that area. Would this be opposed by other teachers' organizations?

Ms. KLEIN. Oh, absolutely not. I think that that would be encouraged. One of the biggest disadvantages that we have heard from industry with this regard is that they do have their own methods, their own way of doing things, and by the time they get the teacher really trained to do the things they want them to, it is time for the teacher to go back into the classroom, and it is very difficult for them to be as productive as industry would like for them to be.

The other real problem is the teachers do become involved and interested in this particular activity that they are doing, and they really have great difficulty then going back into the classroom. And this is one of the things——

Senator SCHMITT. If I can make this much money in 3 months, just think of what I can make in 12.

Ms. KLEIN. Industry has really said that if they would take teachers for the summertime, there would have to be a specific statement signed that they would not leave the classroom. So we have heard both sides of that in our seminar last summer.

I think I need to point out one other thing. That if business and industry could be worked through, I think that would just be marvelous. But by the same token, I feel that each business and industry would have their own sets of guidelines and it would be very difficult to try to have some umbrella sort of arrangement. But believe me, we would be more than willing to work with anyone if we felt that this could be worked out.

Senator **Schmitt**. Your highest priority is for 4,000 NSF undergraduate scholarships in math and science teaching. At about $1,500 a piece, how many additional students do you believe would be attracted to the teaching profession, beyond the number who have chosen that course anyway, by such a program?

Mr. **Aldridge**. Well, it certainly would not—it would not provide the full number that is needed, and that program alone would not be sufficient to solve the problem. And, of course, that is a long-term solution; that does not do anything about the near term.

The funding listings that we have in our statement are not in priority order, Senator. I think our first priority, if we had one, would be—let me turn it around quickly. There is roughly in science education at the precollege level—say in secondary schools in the United States there is probably $20 billion being spent. NSF is not going to solve the problems and we know that and you know it. We know that the Federal Government cannot assume full responsibility for that, or even a major responsibility.

What we are looking for is the catalytic aspect and a symbol and, to some extent, a real high leverage in some areas where something can be done, and we are convinced that some of these inexpensive, highly successful teacher programs could help bring the marginally qualified and those who have not had their upgrading over a long period of time. We are convinced that a small amount of money can have a great deal of leverage and can produce some other effects; that is, can produce some interest and some activity, on the part of others who would contribute their resources.

Senator **Schmitt**. Well, one thing we have to make sure, though, is that the money we put into science teaching does not just educate more scientists and engineers that are going to be hired away from that profession. I am for both things happening.

But the immediate problem we are facing here today, along with all the others, is to get more qualified science and mathematics teachers in the elementary and secondary schools, and in addition, to making sure that students are there, interested and motivated to partake of the teaching that they would supply.

And so, whatever we do with respect to increased funding or reallocation of funds in the NSF toward the same, I think the program also has to include incentives for industry to leave these people in the profession and incentives for people to stay in the profession. And that is the challenge.

We are going to have to move on. We will have some questions for the record which we hope can be answered. We want to thank all of you for being here, and particularly, for Mary coming all the way from New Mexico to be with us not only today, but for 2 months, is it?

Ms. **Beavis**. Yes.

Ms. **Klein**. We would like to thank her for coming to help us and to be in our office for a couple of months so that we can try to get a little bit more done. It has just been a big help to us to have her here and to be able to discuss this with another teacher. I have just really welcomed having Mary with us.

Senator **Schmitt**. Well, New Mexico may have a slightly different environment, where there is an increasing interest at the parent and student level in science and engineering and mathematics. I hope that is the case. Certainly, those are the outward symptoms.

Ms. **Klein**. That is true.

Senator **Schmitt**. Whether we are ready to handle it or not is another issue. That is a national problem and independent of how much interest the students may have. Thank you very much.

Ms. **Klein**. Thank you.

[The statement follows:]

STATEMENT OF SARAH E. KLEIN, PRESIDENT, NATIONAL SCIENCE TEACHERS ASSOCIATION

The following testimony is presented by Sarah E. Klein, President of the National Science Teachers Association (NSTA). The NSTA is the largest science education organization in the world. It is the only science education organization that is concerned with the professional aspects of science education at all levels for all science disciplines.

Mrs. Klein is an 8th grade general science teacher at Roton Middle School, Norwalk, Connecticut. She is currently on leave to carry out her responsibilities as President of NSTA. Mrs. Klein has been active in NSTA for many years, and over the past year has visited schools, talked to teachers, and participated in numerous science meetings throughout the United States, Canada, England, and France. Mrs. Klein wishes to acknowledge the efforts of Bill Aldridge, Executive Director of NSTA, and of James Shymansky, of the University of Iowa, for documentation and preparation of this testimony.

THE CRISIS IN SECONDARY SCHOOL SCIENCE AND MATHEMATICS EDUCATION

Our nation faces unprecedented problems in science and engineering education. Most severe of these problems are at the secondary school level where there is a critical shortage of qualified science and math teachers. The paucity of supplies, resources, appropriate materials, and support have reduced the quality of science and mathematics education at the secondary school level to a point that U.S. national security and the nation's efforts toward improved productivity are dangerously threatened.

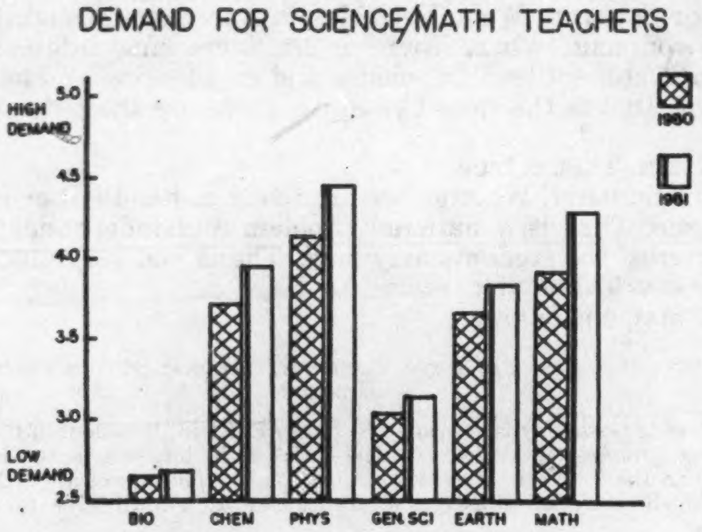
SHORTAGES OF SECONDARY SCHOOL SCIENCE AND MATH TEACHERS

In the fall of 1980 and again in the fall of 1981, Howe and Gerlovich (1) surveyed the 50 state science supervisors to assess supply and demand for secondary school science and math teachers. Shortages were found for 1980-1981, and those shortages have become more severe in 1981-1982. As shown in Table I, this problem is national in scope, and the shortages are critical in physics, mathematics, and chemistry.

TABLE 1.—SCIENCE/MATH TEACHER SHORTAGES

	Critical shortage		Shortage	
	1980-81	1981-82	1980-81	1981-82
Subject:				
Physics	21	27	22	15
Math	16	18	19	25
Chemistry	10	9	25	29

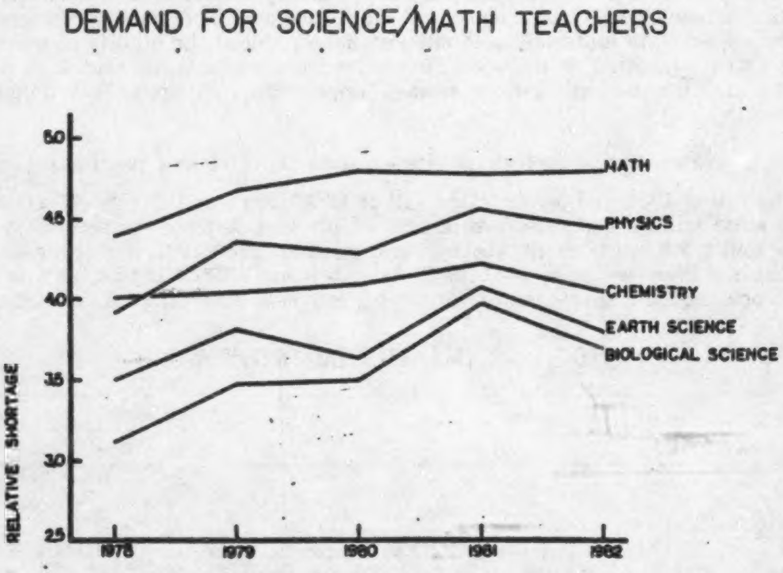
When the science and math teacher shortage problem is expressed in terms of demand, as indicated on a scale from 0 to 5, the results, shown in Figure 1, lead to the conclusion that the shortage has been critical and has worsened in the last year.



Based on a survey of state certification departments. From Trevor G. Howe and Jack A. Gerlovich, "National Study of Estimated Supply and Demand of Secondary Science and Mathematics Teachers," Iowa State University, 1982.

FIGURE 1

In surveys of placement officers conducted by James Akin (2) from 1978 to 1980, "considerable shortages" of teachers were found for math, physics, chemistry, and general science.



Based on a survey of teacher placement officers. From James N. Akin, ASCUS Report, "Teacher Supply/Demand," 1981.

FIGURE 2

SEVERE DECLINE IN NUMBERS OF PERSONS PREPARED TO TEACH SCIENCE AND MATH

In December, 1981, the NSTA surveyed 600 colleges and universities that have teacher training programs (3). Year-by-year data were acquired for the ten-year period of 1971–1980. The results shown in Table II and Figures 3 and 4 are shocking. There has been a 77 percent decline in the number of math teachers and a 65 percent decline in the number of science teachers prepared to teach in secondary schools. As shown in Table II, not only has the supply of persons trained to teach science and math severely declined, but the fraction of those trained who do go into teaching has also declined.

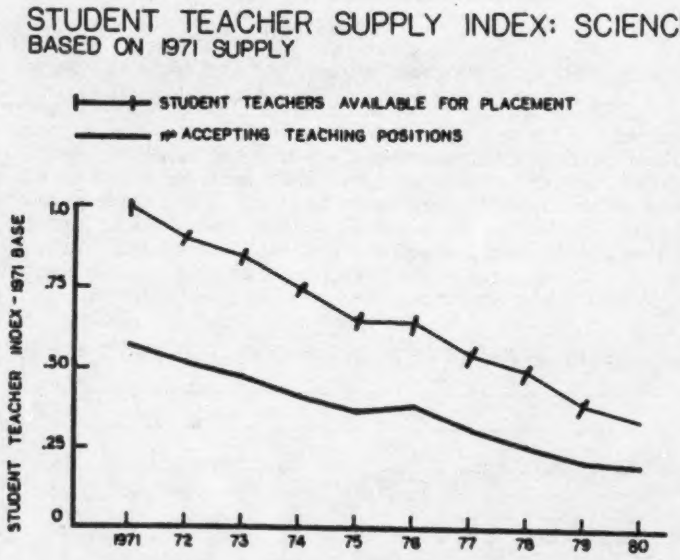
The combined effect is a 68 percent reduction in newly-employed science teachers and an 80 percent reduction in newly-employed math teachers since 1971.

TABLE 2.—SCIENCE/MATH TEACHER SUPPLY DATA 1971–80 [1]

	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Science:										
Graduating teachers............	100	90	85	75	65	65	55	50	40	35
Percent entering teaching....	59	58	58	55	56	59	56	52	54	54
Math:										
Graduating teachers............	100	91	86	73	60	45	36	27	27	23
Percent entering teaching....	63	68	64	65	62	61	63	59	60	55

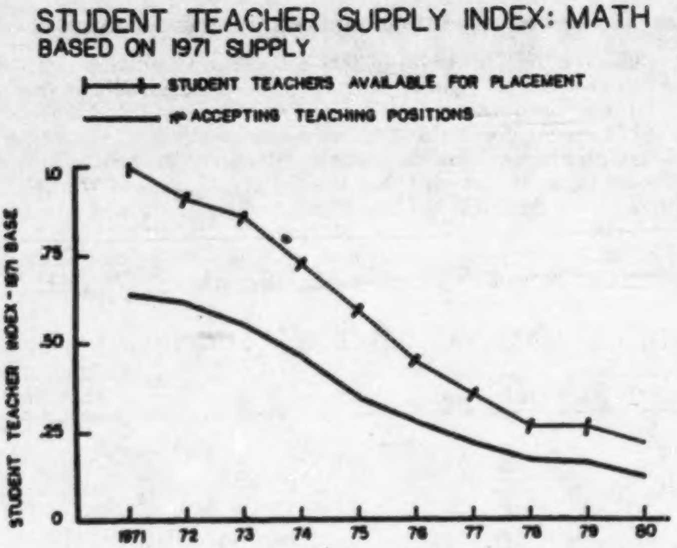
[1] Values represent percentages indexed to 1971.

Note.—Based on data from a nationwide sample of 140 university/college placement officers.



Based on NSTA survey of college and university placement officers. Conducted by J. A. Shymansky, The University of Iowa, 1982.

FIGURE 3



Based on NSTA survey of college and university placement officers. Conducted by J. A. Shymansky, The University of Iowa, 1982.

FIGURE 4

EMPLOYMENT OF UNQUALIFIED SCIENCE AND MATH TEACHERS

In another NSTA survey (4), also conducted in December, 1981, and analyzed by James Shymansky of the University of Iowa, secondary school principals provided the information. Among newly-employed science and math teachers, 50.2 percent were unqualified to teach science or math. They were employed on an "emergency basis" because no qualified teachers could be found. When these data are examined by census region, the results are especially bad in states where high technology industries require the best-trained science and math personnel. Table III shows, by census region, the percentages of newly-employed science and math teachers for the school year 1981–1982 who are unqualified to teach these subjects.

TABLE III.—PERCENTAGE OF NEWLY EMPLOYED, BUT UNQUALIFIED SCIENCE AND MATH TEACHERS

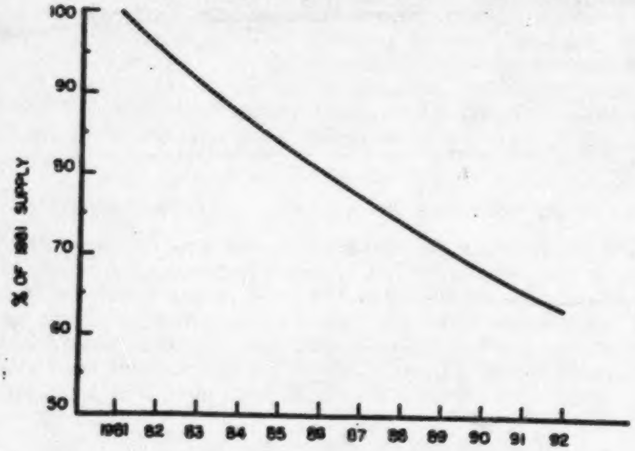
Census region	1980-81	1981-82
Pacific States	75	84
Mountain States	44	43
West North Central States	26	43
West South Central States	63	63
East North Central States	23	32
East South Central States	43	40
Northeastern States	11	9
Middle Atlantic States	40	46
South Atlantic States	48	50
Nationwide	45	50

AGES, EXPERIENCE, AND PLANS OF SCIENCE AND MATH TEACHERS

The evidence of a severe shortage of science and math teachers at the secondary school level is overwhelming. To compound this problem, results of an NSTA survey of science teachers show that schools have an aging faculty and that one in four of the younger faculty plan to leave teaching completely. The average age is 41, and the average experience is 16 years. Almost 5 times more science and math teachers left teaching last year for employment in non-teaching jobs than left due to retirement. If the present exodus of qualified science and math teachers from secondary schools continues, the nation will have a new loss of 35 percent by 1992.

EXODUS FROM THE CLASSROOM

-A PROJECTION-



Based on the 4% rate at which science and math teachers left classroom teaching in the years 1980 and 1981.

FIGURE 5

SCHOOL POPULATIONS—INCREASING OR DECREASING?

Analyses of population data and of school projections compiled by the National Center for Educational Statistics suggest that science and math teacher demand will increase over the next several years.

Elementary school enrollments bottomed out in 1981 and are now on the rise. Secondary school enrollments will by 1996 have dropped only by 24 percent from their high in 1977. Then they will increase again for several years. The declines in qualified science and math teachers has already exceeded these enrollment declines by a factor of three.

CONCLUSIONS ABOUT TEACHER SHORTAGES

Independent recent surveys all show a severe shortage of secondary school science and math teachers. There has been a catastrophic decline in the number of persons prepared to teach science and math, and of those prepared, many do not take teaching positions. Secondary schools are employing record numbers of unqualified persons for science and math teaching positions because qualified teachers cannot be found. The problems are most severe in regions of the country where the greatest efforts will be made for defense preparedness and high technology industry. Thus there is a dangerous mismatch between scientific and technological training capability and national need.

QUALITY OF SCIENCE AND MATHEMATICS EDUCATION

The severe shortages of secondary school science and math teachers and the resulting employment of unqualified teachers on an emergency basis is a major factor in the decline of quality in secondary school science and math education. For the teachers who remain in the science and math classroom, there are other constraints which have made the situation deteriorate further.

From the recent NSTA survey, we know that 60 percent of science teachers report recent cuts in their budgets for supplies and equipment. These cuts occur at a time when school labs are already obsolete, and when computers and other components of modern electronics are essential in an up-to-date curriculum. From the same survey, we learned that 79 percent of these teachers had not completed at least a 10-hour course or workshop in over ten years. Also, 69 percent have never attended a computer course or workshop. Finally, 40 percent have not attended a course or workshop since they began teaching, which has been an average of 16 years.

In another recent national survey conducted by NSTA, elementary school teachers provided the responses (5). Approximately 51 percent report that their undergraduate training did not prepare them to teach science. Furthermore, 71 percent of the school districts had no inservice training for science, and 64 percent no longer had science consultants assigned to their schools.

There has been much public discussion of declines in SAT scores, but less attention has been given to declining scores in the national assessment. There has been a decline in recent years, and now those declines are affecting even our best science and math students.

PRIOR NSF SUPPORT OF SCIENCE AND ENGINEERING EDUCATION

There is, among those in the Administration, and among many others, the mistaken belief that science education has received substantial support, especially in recent years, and that since we now see all of these serious problems, the infusion of massive federal support has been a failure. The facts are quite the opposite. The NSF support for science and engineering education has been declining steadily and steeply for the past 22 years. Figure 6 shows how science education's share of the total NSF budget has dropped from a high of 47 percent in 1959 to its present low of 2 percent.

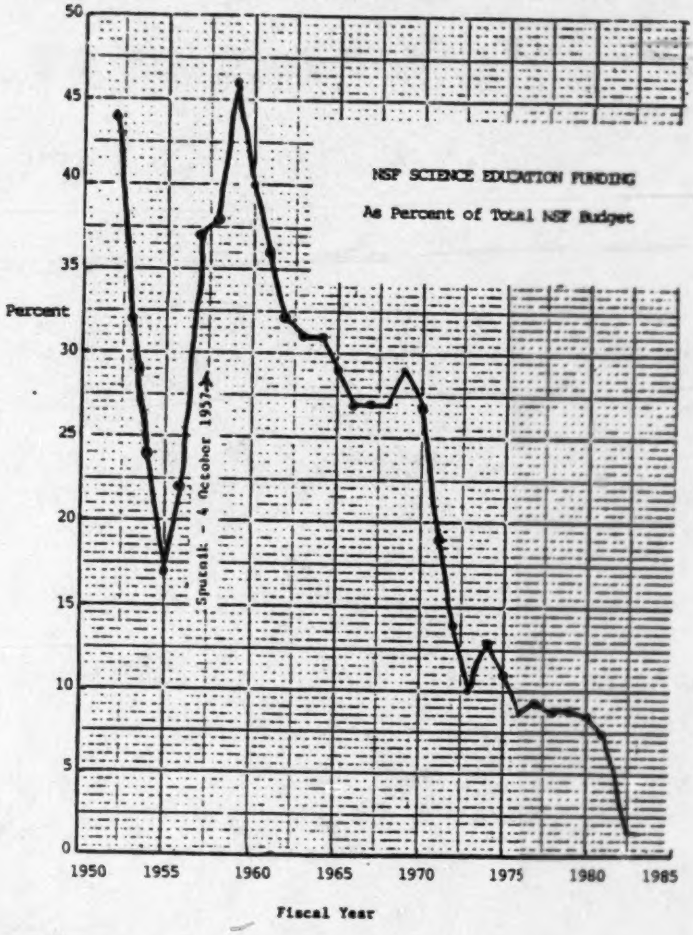


FIGURE 6

Support for pre-college science education has dropped even more sharply, from 72 percent of the science education budget in 1959 to 22 percent in 1980. In terms of the total NSF budget, the pre-college share has dropped from 34 percent in 1959 to its present low of less than 1 percent.

The NSF support for secondary school science and math has fallen to a negligible level, and the present cluster of national problems in secondary school science and math education can in large part be attributed to NSF's negligence of the component of their Congressionally mandated mission. Figure 7 shows how the decline in NSF support at the pre-college level correlates with declining achievement in science as measured by the National Assessment of Educational Progress. Although correlations do not necessarily mean cause and effect. But coupled with all the other evidence, this correlation may well be as good an indicator of a direct relationship as is the case of smoking and cancer.

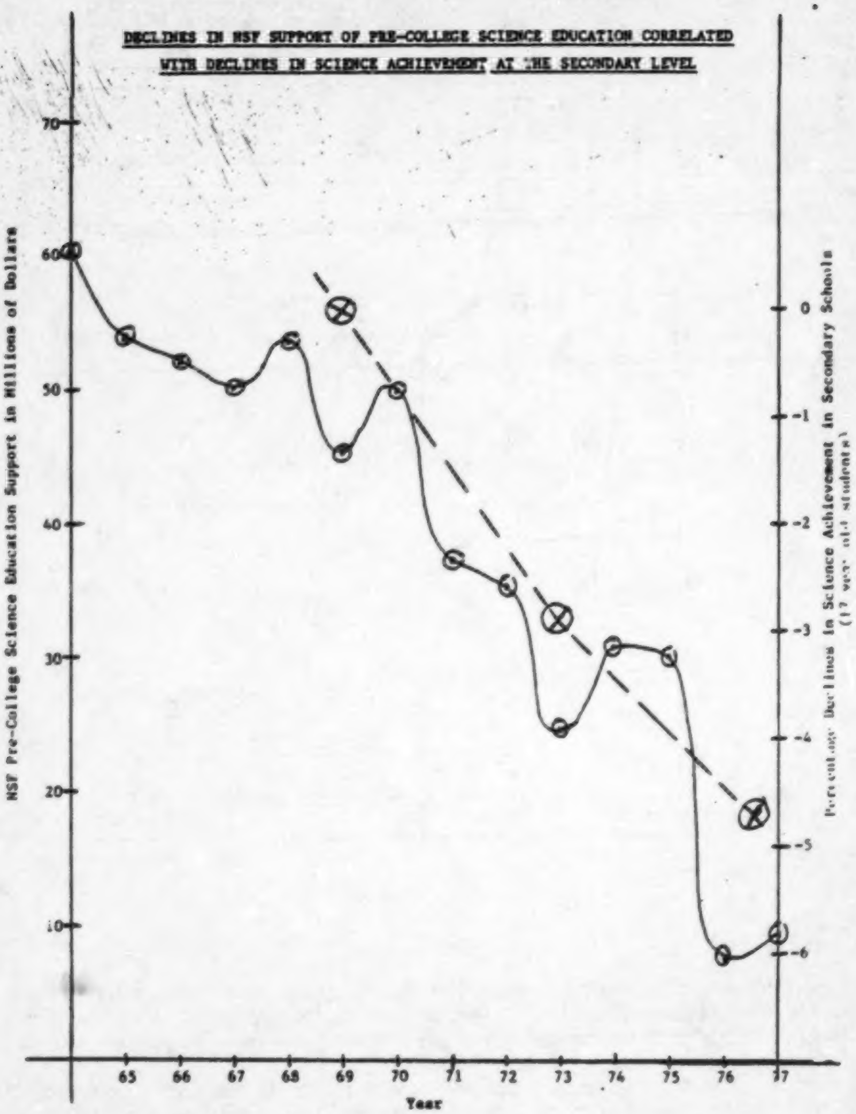


FIGURE 7

NSF CURRICULUM DEVELOPMENT PROJECTS

Much of the demise of NSF's science education support has resulted from criticisms of curriculum development activities. There are legitimate criticisms that one can make of the "new curricula" produced under NSF support: Those projects often purged applications, concentrated heavily on pure science, and appealed mainly to the very brightest students. Their difficulty level contributed to the reduction in the numbers of students studying science and mathematics in recent years. Yet, according to preliminary results of a very recent project (6), the new curricula were far more successful than most people realized. In this project, an analysis was made of 105 studies involving 45,000 students. Comparisons were made between students enrolled in new science curricula and traditional curricula. On every kind of measure, including achievement, attitude, and process skills, students taking the new NSF curricula scored overall 14 percent higher. For the BSCS Biology and Chem Study materials, the students scored higher by more than 17 percent. What is most significant is the fact that students from low socio-economic groups scored 24 percent higher using new NSF-supported curricula than traditional curricula. Since a larger

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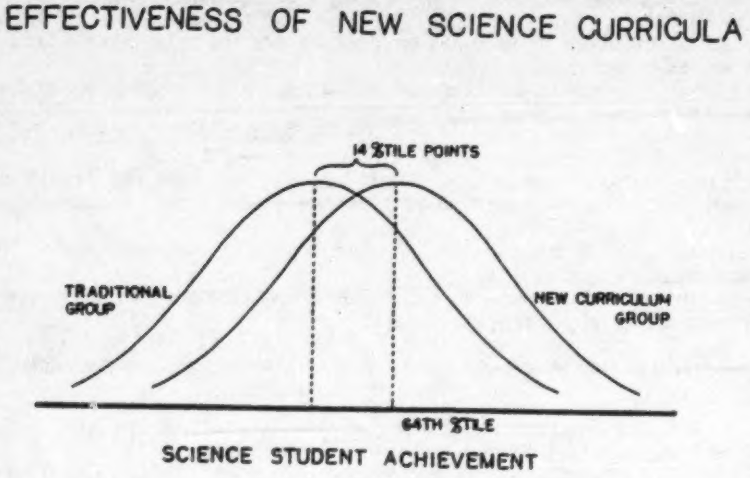
proportion of our minority population are in the low socio-economic categories, the new curricula, supported by NSF, gave minority children a decided edge over similar children exposed to traditional materials.



Composite effect of student performance across all new science curricula based on student sample, N=45,000. From Anderson, et al., NSF Grant SED 80-12310.

FIGURE 8

These studies covered a period of several years in the 1960's and 1970's. Few teachers are left in the schools now who are qualified to teach such curricula, and essentially none have been given the in-service training to do so since NSF abandoned that kind of program several years ago. Also, the materials are badly in need of revision and modification to take into account computers, modern electronics, and applications to technology. The problem of offering appropriate science to less able children also must be addressed.

COMPARISONS OF U.S. AND U.S.S.R. SCIENCE AND MATH EDUCATION

Recent comparative studies (7) in science and engineering education between the Soviet Union and the United States suggest a major offensive by the U.S.S.R. to increase its economic productivity and defense preparedness through science and engineering education. The U.S.S.R. offers its pre-college students sequences of course material in science and mathematics starting with an intuitive level of understanding. Then students progress to empirical levels; finally, they are ready for the formal axiomatic and theoretical understandings. The actual time spent begins with only a couple of hours per week and changes gradually over three or four years until students spend four to five hours per week in class. Thus the Soviets not only offer all students quantitatively more contact with the sciences and mathematics, they do so systematically to ensure that students progress in a way that matches stages of intellectual development. In U.S. secondary schools, and in colleges, students enter a course in physics or chemistry and are immediately introduced for the first time to the highest levels of abstraction, without any intuitive basis or prior empirical knowledge. Thus many find these subjects hopelessly difficult and fail or drop out. Most students simply avoid taking these subjects, having heard how difficult they are. The lack of application in science curricula and their failure to relate to personal and societal problems and issues further alienate students.

WHAT ARE THE PRIORITY PROBLEMS?

The most critical problems are at the pre-college levels, especially in secondary school science and mathematics. Those problems are, in order or priority:

(1) Critical shortage of physics, mathematics, and chemistry teachers at the secondary school level;

(2) Substantial numbers of unqualified persons are teaching science and mathematics in secondary schools;

(3) Most certified science and mathematics teachers at the elementary and secondary levels are badly in need of in-service training;

(4) New sequences of science and math courses and materials are needed which match stages of intellectual development of children;

(5) Elementary school science consultants are needed who understand science, stages of intellectual development of children, and who know what resoures are available;

(6) Elementary and secondary schools need access to microcomputers, low-cost supplies, and other resources; and

(7) Science curricula need revision, and teachers need training in using new materials and new methods of sequencing content.

CAN LOW-BUDGETED NSF PROGRAMS HELP SOLVE SCIENCE EDUCATION PROBLEMS? ARE THERE TOO MANY PROGRAMS?

Among the reasons given for eliminating science education from NSF is one that is specious at best. It takes a form something like the following:

The NSF science education effort had grown into many diffuse, low-funded programs without coherence and were therefore ineffective in dealing with the worsening problems. This argument is usually offered by the very persons who have assisted in reducing the support for science education or by those intent on eliminating science education support for ideological, not economic or even political reasons.

Now consider the facts. The 28 or so "programs" of the Science Education Directorate were not programs any more than are the 28 "programs" listed for the Engineering Directorate in the 1982 NSF Budget document. Just as Engineering has four main programs with 6 or 7 program elements for each main program, science education had four main programs:

I. Science Personnel Improvement
II. Science Education Resource Improvement
III. Science Education Development and Research
IV. Science Education Communications

The various components fit in a reasonable and coherent way to the program thrusts.

The average science education program element was budgeted at about $2.86 million in 1980. In the 1982 Engineering Directorate, the average of those 28 program elements is budgeted at $2.75 million.

TABLE IV

[Dollars in millions]

	Science education directorate 1980	Engineering directorate 1982
Main programs	4	4
Program components	28	28
Budget	$80	$77
Average program element budget	$2.86	$2.75

If one looked at the individual engineering sub-elements in 1982, he could easily draw the conclusion that the Engineering Directorate was diffuse and ". . .targeted at specific, limited problems without any very clear connection to a larger conception," a statement made recently by Dr. John Slaughter in referring to science education.

The preemptive NSF reorganization, effective March 21, 1982, eliminated the Science and Engineering Education Directorate, replacing it with an Office of Scientific and Engineering Personnel and Education. Staff have been reduced from over 100 in 1980 to 15. This elimination of the science education mission of NSF, if sustained by the Congress, will have been effected with tacit, if not explicit approval and cooperation by a majority of scientists in and out of NSF whose main concern is to protect research support at all costs. Yet most of the people who have ever heard of NSF or have been directly affected in positive ways by NSF, had contact through NSF science education programs. This abandonment of science education will ultimately prove short-sighted in the extreme.

NSF'S 1982 BUDGET FOR SCIENCE AND ENGINEERING EDUCATION

Of the $20.4 million appropriated for NSF science education for 1982, $15 million was for graduate fellowships. Some $700,000 was designated to support a "commission," and the balance was used to meet "prior obligations."

Since graduate fellowship support is but another form of support for scientific research, the NSF has essentially eliminated all science education activities. The Administration has successfully forced NSF to abandon one of the missions required by its enabling legislation. It is time that NSF ask Congress either to change the NSF organic act and delete science education from NSF's mission or stop the deception that graduate student support alone is somehow equivalent to support of science education at all levels and proceed with its responsibilities by providing a budget which addresses serious national problems in science education.

THE SPECIAL COMMISSION ON SCIENCE AND ENGINEERING EDUCATION

The only new activity for science education in the 1982 budget was $700,000 to support a special commission on science and engineering education. The NSF spent upwards of $3 million over the past five years for studies at the pre-college level. There is ample evidence of what the problems are and what is needed to solve them. What is now needed is federal action to address documented and serious national problems. Regardless of the potential value of the commission, there can be no justification in waiting 18 months for its recommendations before funding other appropriate science education programs.

If a major problem faced physics research, we would not stop all other physics research while we "studied" the problem. The National Science Teachers Association will assist the commission in every possible way, but we strongly recommend that the Congress provide 1983 funds to attack the most severe of the problems already identified and documented.

THE FEDERAL ROLE—AN NSF SCIENCE EDUCATION PROGRAM FOR 1983

The critical shortage of secondary school science and math teachers cannot be solved in 1983. This is also a problem which must ultimately be solved at the state and local levels. Compensation for science and math teachers must be competitive with those in industry. Even though the federal government cannot solve the salary problem, there are other federal measures which can help reduce the severity of this problem. The long-term shortages can be addressed by stimulating new entrants to teachers training programs in science and mathematics. This can be accomplished through NSF scholarships and NSF-supported programs of publicity on the need for teachers.

Problems of quality can and should be addressed at the federal level. In the short term, the NSF could support summer and academic-year courses and workshops for marginally-qualified science and math teachers, so that they may reach some minimal level of qualification to teach the assignments they have been given. NSF has considerable experience with such programs. If they are administered without stipends, they can be extremely cost-effective.

The problem of establishing new sequences of science and math courses to match the stages of intellectual development of children is most difficult to solve. Since this problem is really one of research and development, it cannot be justified by a local school system or a state government. It is appropriately a federal responsibility. The most cost-effective solution would be for the NSF to support development and implementation of a model sequence in two or three school systems. These models would be carefully developed in cooperation and with assistance of scientists and science education experts at universities. Detailed guidelines for establishing the sequence would be prepared and widely disseminated. The NSF might then provide support only for consultant services to shools that chose to implement the approach, using the guidelines which had been developed.

The problem of upgrading qualified science and math teachers can be solved by offering short courses and workshops. The NSF has models of these already in operation and could easily continue these programs.

The need for low-cost supplies and other resources can be addressed by NSF through a program of support for area Science Instruction Resource Centers, modeled after the one created by Douglas Lapp in the Fairfax, Virginia School District. Since teaching resources should be a local responsibility, funds should be provided only for establishing the centers, with a complete phase-out of federal funds over a two-year period.

Microcomputers could be supplied through an NSF program of partial support. Even a level of support by NSF of 25 percent of the cost could have great leverage in bringing larger numbers of microcomputers into the schools. Again, equipment is a local responsibility, but a small matching federal fund could stimulate great local expenditure. Also, when there is one computer present in a school, the demand increases rapidly, and schools find ways to purchase additional units. Given the availability of in service programs for teachers, proper utilization could be assured.

The revision of curricula to bring them up to date and to accommodate to the new technology, applications, and societal problems, can be accomplished through conventional, but carefully monitored, curriculum development projects. Such projects are the most easily justified as federal responsibility, since the resulting materials are used throughout the nation.

The problems of elementary school science are immense, but a high-leverage approach, with relatively low cost, would be an NSF program of summer and in-service studies for science consultants. Also, some modest one-time grant support could be provided to school districts that were willing to reinstitute a science consultant program for their elementary schools.

DOES THE AMERICAN PUBLIC THINK THAT TAX FUNDS SHOULD BE USED BY NSF TO SUPPORT SCIENCE EDUCATION AND BASIC RESEARCH OR JUST BASIC RESEARCH?

The Thirteenth Annual Report of the National Science Board, "Science Indicators 1980," dated March 31, 1981, offers much interesting and useful information.

The table below is taken from that NSF report. According to this report to the President, the Public would rank science education *second* as its choice "to receive science and technology funding from tax money." The Public would rank basic scientific research *tenth* in its choice to receive such tax money. Science education is even ranked ahead of national defense.

Given clear evidence of public preference for spending tax money for science education over spending it for basic research, and given the Congressional mandate in the organic act of NSF to support science education at all levels, it is most difficult to understand why NSF is forced to ignore this responsibility.

APPENDIX TABLE 6-10.—AREAS THE PUBLIC WOULD MOST LIKE TO RECEIVE SCIENCE AND TECHNOLOGY FUNDING FROM TAX MONEY: 1972-79

Area	Percent in 1979	Rank[1]			
		1972	1974	1976	1979
Improving health care	50	1	1	1	1
Developing energy sources and conserving energy	46	([2])	([2])	([2])	([2])
Improving education	39	5	[3]4	[3]3	(2)
Reducing crime	36	3	2	2	3
Developing or improving methods for producing food	23	([2])	([2])	([2])	([2])
Reducing and controlling pollution	22	2	3	[3]3	4
Developing or improving weapons for national defense	16	[3]10	[3]11	[3]8	[3]5
Preventing and treating drug addiction	16	4	[3]4	5	[3]5
Developing faster and safer public transportation within and between cities	13	7	7	7	7
Improving the safety of automobiles	9	6	6	6	8
Finding better birth control methods	9	8	9	[3]8	9
Discovering new basic knowledge about man and nature	8	9	8	10	10
Exploring outer space	6	[3]10	[3]11	11	11
Predicting and controlling the weather	4	[3]10	10	12	12
	(N=1,635)				

[1] In 1979, respondents were asked to limit themselves to three areas, and slight changes in the wording of some items were made.

[2] "Developing energy sources and conserving energy" was not included in the listing prior to 1979 and "developing or improving methods for producing food" was not included prior to 1976. These areas were therefore omitted from the rankings.

[3] Tied for the indicated rank.

Sources: Attitudes of the U.S. Public Toward Science and Technology. Study III (Princeton, N.J.: Opinion Research Corporation, 1976), pp. 56–57; Jon D. Miller, Kenneth Prewitt, and Robert Pearson, The Attitudes of the U.S. Public Toward Science and Technology (Chicago: National Opinion Research Center, University of Chicago, 1980), p. 137.

IS THE NSF PROVIDING MORE SCIENCE AND ENGINEERING EDUCATION SUPPORT TO GRADUATE STUDENTS FROM FOREIGN NATIONS THAN TO AMERICAN CHILDREN?

The answer is yes! Some 90 percent of all science and engineering graduate student support is from research assistantships. At least 20 percent of the funds from research grants are used to provide research assistantships. Over 20 percent of all graduate students in science and engineering are foreign nationals (40 percent of those in engineering are foreign nationals). If we consider only basic research funding of $5.9 billion, we see that the U.S. Government subsidy to foreign nationals in science and engineering education is more than $200 million. This is more than twice the NSF science and engineering education budget in 1980. Thus, while such nations as Iran, Japan, and Saudi Arabia use their resources to educate their children in science at the pre-college level, the U.S. neglects the science education of its children while providing a U.S. subsidy for graduate education in science for young people from competing nations.

WHERE ARE THE FUNDS FOR SCIENCE AND ENGINEERING EDUCATION?

The Administration's proposed NSF budget calls for a total of $1,072.8 million in 1983, an increase of 7.7 percent over 1982. Needed science education programs could be financed by holding the total research and related activities budget to a 2 percent increase instead of the 8.7 percent increase which is proposed. This will free up $65.5 million for science education activities.

NSF science and engineering education recommended program elements for 1983

	Millions
NSF undergraduate scholarships for math and science teaching (4,000 at $1,500 each)	$6.0
Science and math teaching careers publications and dissemination	1.5
Tuition, books, and materials for summer and academic-year courses and workshops (5,000 marginally-qualified teachers at $2,000)	10.0
Model sequences for science and math courses (3 projects at $2 million)	6.0
Short courses and workshops for upgrading qualified science and math teachers (10,000 teachers at $1,000)	10.0
Model science instruction resoruce centers (50 at $200,000)	10.0
Partial support grants for microcomputers (25 percent of $2,000 for 10,000 schools)	5.0
Curriculum revision and enhancement projects	12.0
Programs for science consultants for elementary schools	5.0
Subtotal	65.5
Graduate fellowships	15.0
Total	80.5

One of the major arguments used to eliminate science education support is that the problems are too great and these NSF funds too small to have a significant effect. Yet this budget, of only $65.5 million would directly affect 19,000 science and math teachers and 10,000 schools. It would indirectly affect another 50,000 teachers and millons of science and math students in their classes. The program elements of the Science Education Directorate have been and can be the most cost effective of all federal programs. They are more competitive than the NSF research program. Where 5 to 10 percent of science education proposals have been funded, some 30 to 40 percent of research proposals are funded. The NSF science education programs have been and can be of high quality because they are competitive and have never been administered as entitlements. It is the prestige and high quality of the NSF programs which offer the strongest reasons why NSF and not another federal agency should offer these programs.

SOURCES

(1) T. G. Howe and J. A. Gerlovich, "National Study of the Estimated Supply and Demand of Secondary Science and Mathematics Teachers," Unpublished Paper, November 6, 1981.

(2) J. N. Akin, "Teacher Supply and Demand: A Recent Survey," (ASCUS, Box 4411, Madison, WI 53711) 1980.

(3) Preliminary results of December, 1981, NSTA Survey of 600 Colleges and Universities with science and math teacher training programs.

(4) Random sample of 2,000 U.S. secondary school principals in December, 1981. Analysis done by Dr. James Shymansky using staff and computers at University of Iowa.

(5) Preliminary results of survey undertaken in January, 1982, by Kathleen M. Donnellan, NSTA Preschool Elementary School Division Director, Springfield, Massachusetts Publish Schools.

(6) Ronald Anderson, James Shymansky, et al. Preliminary Results of Project NSF SED 80-12310, February, 1982.

(7) C. P. Ailes and F. W. Rushing, "The Science Race: Training and Utilization of Scientists and Engineers, U.S. and U.S.S.R.," Chapters I, II, (Crane Russak, New York) 1982.

QUESTIONS OF THE COMMITTEE AND THE ANSWERS THERETO

NSF COMMISSION ON PRECOLLEGE SCIENCE EDUCATION

Question. Dr. Slaughter has testified before the House Subcommittee on Science, Research and Technology that the Commission on pre-college education in mathematics, science and techology "is not being established for the purpose of conducting yet another study." It is to develop an action plan that "will product preliminary results at the end of 6 months, more substantive recommendations at the end of 12 months, and a final conclusive set of results at the end of the 18-month anticipated life of the Commission." The plan is to identify "specific responsibilities of the NSF, other federal agencies, state governments, local school districts, private industry, private foundations, and citizens at large."

How do you feel that this approach is inappropriate?

You state in your testimony that "what is now needed is federal action to address documented and serious national problems."

Answer. It is inappropriate because it does not begin to address the crisis that exists today, right now. The documented and serious problems that are referred to in the testimony need to be addressed immediately. During the coming 18 months, during which time "a conclusive set of results" is supposed to be arrived at by the commission, essentially 2 years of classes of high school and elementary students will be shortchanged by continuing to be taught by unqualified new teachers and/or marginally-qualified certified teachers.

Question. How should federal action be coordinated with other centers of responsibility for science and mathematics education?

Answer. Federal action coordinated with other centers of responsibility for science and math education could include monetary incentives to prospective teachers

(a) to go into the teaching fields of science and math, particularly the physical sciences and

(b) to stay in the teaching field once training had been completed for a period of 3 to 4 years.

The literature indicates that it takes this amount of teaching time for a beginning teacher to become comfortable and proficient in the teaching field.

Another way would be monetary support to local districts who positively address these stated problems as they occur in an individual community—problems of not having elementary school science coordinators or of retraining or in-service training of marginally-qualified teachers.

PRIVATE SECTOR COST SHARE

Question. As I noted in my opening statement, two major microcomputer manufacturers have offered to donate approximately 100 computers each to the NSF. These machines are to be used in the NSF's program to improve science and engineering education at the 10th, 11th and 12th grade and at the introductory college levels.

How does NSTA view an initiative of this kind?

Answer. One of NSTA's recommended program elements for 1983 includes partial support grants for microcomputers for 10,000 schools. The need is certainly there, and the 200 donated computers is a good beginning effort on the part of the two microcomputer manufacturers. We would hope that more manufacturers would see the advantages of similar involvement in this NSF program.

PRIVATE SECTOR COST SHARE

Question. I stated in my opening remarks that I would explore the idea of making some of the NSF awards contingent on matching funds from business and industry.

Where might such an arrangement be appropriate in addressing our problems in science and mathematics education?

Answer. It would be appropriate if monies freed from such awards could be utilized for setting up math and science teaching scholarships; for tuition, books, and materials for summer and academic-year courses to train marginally-qualified teachers; for upgrading qualified math and science teachers; and for setting up programs for science consultants for elementary schools.

Senator SCHMITT. Our next witness is Dr. Robert Park, chairman, Department of Physics and Astronomy at the University of Maryland, and he is representing the Ad Hoc Working Group on Scientific Instrumentation of the National Research Council.

Dr. Park, if you wish to summarize your testimony you may. It will be included in the record in its entirety. I see that it is not too long, but we will leave it to your judgment, so we can get on into the questions.

STATEMENT OF DR. ROBERT PARK, CHAIRMAN, DEPARTMENT OF PHYSICS AND ASTRONOMY, UNIVERSITY OF MARYLAND, REPRESENTING THE AD HOC WORKING GROUP ON SCIENTIFIC INSTRUMENTATION, NATIONAL RESEARCH COUNCIL

Mr. PARK. Thank you, Mr. Chairman. Let me summarize for just a moment.

More than half of all basic research in the United States is today carried out in universities, and is supported overwhelmingly by the Federal Government. As you stated in your opening remarks, the university-Government collaboration has helped to maintain our position of leadership for many years. But that leadership is now challenged.

There are a number of problems leading to that challenge. You have just heard discussion of one serious problem; namely, the weak preparation in math and science in our elementary and secondary schools. In fact, it was a pleasure to see Mary Beavis here testifying. I have known her for 20 years.

I appreciate today being given the opportunity to discuss another component of the threat to our leadership, namely the declining state of research instrumentation in American universities. You have I think heard previous testimony concerning the circumstances that led to the present problem and estimates of the accumulated need in dollars.

Whether that need is $1 or $4 billion is not I think what concerns us here. It is unrealistic to suppose that either sum of money could be made available under present circumstances. What then can be done?

On March 12 and 13 of this year, the Ad Hoc Working Group on Scientific Instrumentation assembled at the National Academy of Sciences to consider the problem. The group consisted of leaders of industrial research and development laboratories, representatives of various Government agencies concerned with the problem, and university researchers.

The focus of the meeting was on instrumentation in the $50,000 to $1 million range. There was complete agreement between all three segments that the current problem of research instrumentation in the universities seriously threatens the health of the scientific enterprise in the United States, in the short term by its direct effect on scientific research and in the long term by its effect on the training of scientists.

The meeting concentrated on a discussion of ways to ameliorate the problem within existing budgetary constraints. This committee has a first draft of the report of that meeting.

The workshop concluded with a separate meeting of the corporate and university representatives to recommend solutions. George Pake, vice president for research at Xerox, led the industry group. I led the university side. The recommendations of the two groups were remarkably similar.

One recommendation was for increased reliance on block funding. One of the most serious problems I think in research instrumentation at the present time is providing equipment for new faculty and for established faculty, who wish to undertake major changes in the direction of their research programs.

Such changes, I should point out, are a measure of progress. It is inevitable that if we solve problems in research the equipment designed to effect those solutions becomes obsolete. We must not cling to stale or outmoded research programs simply because we have the instruments to work on them. The most straightforward way to approach the problem of seed money is to provide block funding to institutions that can be used flexibly.

There was also a great deal of discussion of creative financing techniques. Anyone who has been living on a faculty salary for a few years understands debt financing. It is, however, a rather novel idea to university administrators, although a few universities have moved in that direction. Universities must be willing to use these techniques for the acquisition of major items of equipment. Such arrangements enable instruments to be financed either through direct use charges against the grants or by inclusion in the indirect cost pool used in computing overhead. But no new money is created and the cost will ultimately appear somewhere else in the research program. It is a short-term solution.

Senator SCHMITT. Or in the bankruptcy courts, if universities can go bankrupt.

Mr. PARK. That is right. There was also discussion of greater reliance on the use of central facilities. There are problems dealing with that approach, and I have discussed some of the cautions in my written report.

There was also agreement that a series of regional tutorial workshops held across the country could do much to encourage the academic community to take an active role in solving the problem. These workshops would involve people from industry, universities and federally funded laboratories. Continued discussion between these three elements of the U.S. scientific enterprise can work to the mutual benefit of all three.

The emphasis, in the workshop as I said before, was on seeking solutions within existing budgetary constraints, and certainly we must make every effort to manage our resources more efficiently. This is, however, only part of the problem. I have worked in corporate and Government laboratories, as well as in university laboratories. In my view, universities do not do all that bad a job of management.

Without new money, we are simply going to push the problem from one place to another. Quite frankly, we will always need more money. The prospects for science are so great that we will never have enough. But the challenge the United States faces right now is to its technological leadership. That leadership has been challenged before and each time Government, industry, and the university have worked together to meet and overcome the problem. We must do the same now.

Senator **Schmitt**. Thank you, Doctor. You said in your written testimony that your academic colleagues were impressed by the approach of their industrial colleagues and were open to suggestions to facilitate planning for a reasonable balance between manpower and capital acquisitions. How would you characterize this industrial approach relative to that generally followed by universities?

Mr. **Park**. It is difficult to compare them. In industry the emphasis, of course, is on applied research. There is a definite goal to be reached. Basic research follows a rather different procedure. In effect, you do next what you can do next. You do not decide what the next problem is until you get to the solution to the one you are working on. So you are sort of following the contours of the land.

It makes it very difficult to plan in the same way that you plan an applied research program. It is, however, a productive, in fact a more efficient, way of getting at basic research results. If we know what the answer is, we probably should not be doing that research. That is very frustrating to auditors. They do not like that kind of planning at all.

What we really have to plan is how to create the flexibility in the system to respond to the situation as it exists. We simply do not know where we are headed until we begin to solve the problems.

Senator **Schmitt**. But what lessons can be taken from the private sector? You have analyzed the difference. Now, what lessons—private sector decisions are in theory overseen by stockholders or by boards of directors, who are supposedly protecting stockholders' interests. And there is some pressure applied to what is undertaken and how it is undertaken as a result of the competitive marketplace.

In universities, a great deal of research is undertaken without being overseen by anyone; is that not correct? It is the success of the individual faculty member in obtaining funds for their research. But in the case of large facilities, at least approval of the board of regents is required.

Mr. **Park**. That is correct. In fact, even small grants require some approvals, and larger grants go simply higher up in the university system. And ultimately, as you say, the board of regents have to pass, certainly on facilities acquisitions, but even on research proposals, because all research proposals involve some obligation of the university, to provide space and so forth. So all of these are passed on.

What we probably do not as well as industry, we do not have as much control, of course, over the use that is made of the instruments. There is a limited extent to which we can control that. Each faculty member is sort of in business for himself. He is responsible for raising his own research funds and hiring his own staff, planning his own research direction.

The judgment that is passed on him is passed on him at salary time and—but the real judgment comes from his peers in seeking the grant money. He prepares a proposal and the proposal is going to be scrutinized by the very people he is in competition with. So there is a check. It is a different kind of check than industry has, and perhaps we do not share our resources as well as industry does, although I do not think we do that bad a job.

Senator SCHMITT. What were the issues which the university caucus and the industry caucus could not agree on?

Mr. PARK. I think there were no major areas of disagreement.

Senator SCHMITT. None whatsoever?

Mr. PARK. None.

Senator SCHMITT. Was it discussed whether or not there were ways in which limited Federal dollars could leverage significant industrial dollars?

Mr. PARK. Yes, there was some discussion of that. I have absolutely no doubt of the willingness of industry to participate in reasonable approaches to solving these problems. In fact, industry has been helping us right along.

At the University of Maryland, we have a College Engineering Advisory Council that is made up of leaders of industry, including William Baker, the former chairman of the board of Bell Telephone, vice presidents from Westinghouse and Dupont and other major companies. These people have helped us enormously. They go to Annapolis to lobby for us at budget time. They give us feedback on what industry's needs are and the direction that technology is moving.

They have provided us individually from their companies with scholarship aid, teaching equipment, all sorts of things. Their involvement tends to be more in the classroom teaching aspect than directly in the research. But there is no question but what they are interested in the problem and have already provided a great deal of help.

Senator SCHMITT. What if the NSF instrumentation moneys, whatever they may be, were provided on a 1-to-5 match for industry funds? Would that have any effect at all? Would industry walk away from it? Would it help them sell it to their board of directors or what?

Mr. PARK. I wish one of my industry colleagues from that meeting were here to address that. It is my impression that they would not walk away from it. In view of the size of the problem, I do not know from their balance sheets how much they can bring to bear. That is a question I cannot address. Certainly I have no doubt of their willingness to do what they can.

Senator SCHMITT. Does the industry caucus, with which you have worked, believe it is generally the obligation of the public sector to provide the raw material represented by people, and it is industry's responsibility to provide raw materials that are nonpeople in nature?

Mr. PARK. I think that would be a fair characterization.

Senator SCHMITT. Do you agree with that characterization?

Mr. PARK. I think that is basically right.

Senator SCHMITT. Why is it not in the self-interest of the industry to insure that that the people resource is available?

Mr. PARK. Oh, I think they are interested in insuring that it is available. I do not think they regard it as their primary responsibility.

Senator SCHMITT. They are taking it for granted that it is always going to be there, are they not?

Mr. PARK. Well, they take it for granted that the Government they support from their taxes is going to provide it, I think.

Senator SCHMITT. You think that is one of the principal purposes to which taxes should be put?

Mr. PARK. Well, I am trying not to be cynical about that. As I say, we get enormous cooperation from industry. I cannot recall a problem in which we have not gone to industry and not gotten cooperation. I cannot speak for them as to how much resources they can bring to bear on any of these problems.

Certainly, they recognize that they are absolutely dependent on the universities. They know that and they know that their success depends on how good a product they get. Certainly they want to help.

Senator SCHMITT. But industry is generally coming in here and elsewhere and saying that the universities are not turning out enough graduate degree holders in science and engineering. At the same time they are hiring away the very best, once they get the baccalaureate degree.

Mr. PARK. It is an extremely difficult problem. In an area like electrical engineering, in microcircuit fabrication, it is virtually impossible to hire an assistant professor, that is true.

Senator SCHMITT. Well, what is their answer? It sounds to me that there is an area of disagreement here. Do they not feel that they have a responsibility to help the universities solve this problem? Do they really think that the people in the Maryland State House or in the Congress are going to allocate the level of dollars necessary to make it competitive to stay in the university system, either as a student, graduate student, or as an assistant professor?

Mr. PARK. No. As a matter of fact, one of the solutions that we have experimented with at the University of Maryland already is for scientists from industry to spend some time teaching. And we do have these exchange programs both with industry and with Government laboratories, which work extremely well.

Senator SCHMITT. But has that solved your shortfall?

Mr. PARK. No, it has not solved the problem, but it certainly has alleviated it.

Senator SCHMITT. What is the shortfall of assistant professors in science and engineering at the University of Maryland, do you know?

Mr. PARK. Well, it varies greatly by area. I know that there was an attempt made to add four assistant professors in the area of microcircuits and we were unsuccessful in securing a single one. During the same period of time, we added six assistant professors in areas like control theory and other areas that are very important. But in certain areas it is exceedingly difficult right now.

Now we have—there is greater success in hiring at the senior level. We can do better hiring, I think, full professors out of industry than we can assistant professors.

Senator Schmitt. How many full professorships can you afford?

Mr. Park. Not very many.

Senator Schmitt. I think the shortfall at the University of New Mexico in their engineering department is approaching 20 percent right now.

Mr. Park. I am not surprised.

Senator Schmitt. Are there any universities currently using debt financing for the acquisition of instrumentation?

Mr. Park. Yes, two universities—well, one university in particular, Colorado State University, has been very active in this. And I look at this with great admiration. It looks almost like wizardry to me. They have floated bond issues, they have done all sorts of things in order to acquire equipment.

As I say, I am impressed by that. I think we have to do more of it. It gets equipment right now, when we need it. But again, without the infusion of new dollars you wonder where the problem is going to show up, and my guess, it is going to push part of the problem down to instruments of smaller cost.

Senator Schmitt. Are you aware of industrial revenue bonds ever being used to finance university instrumentation?

Mr. Park. I think that has been done at Colorado State.

Senator Schmitt. Where?

Mr. Park. At Colorado State.

Senator Schmitt. Colorado State.

Do you see equipment manufacturers providing any instrumentation at this time, for whatever purposes they might be able to rationalize?

Mr. Park. More I think in science teaching than in science research. There are two kinds of problems in scientific instrumentation. One needs a certain amount of standard equipment for analytical purposes and this kind of thing within a research program. But the instrument that you actually do the research with, if it is really basic research, is essentially one of a kind. And so it is the peripheral support equipment that you are concerned about in this kind of a situation, but there is also the problem of constructing equipment, one of a kind equipment. There will not be any donations of that.

Senator Schmitt. Has anyone ever estimated the cost to industry of retraining new employees on modern, up to date equipment, relative to the cost of having that equipment generally available within the university system?

Mr. Park. No, I do not know of any. If such a study has been done, I am not aware of it.

Senator Schmitt. Any guesses? Would it be cheaper to supply the universities with modern equipment, updated periodically, than it is to basically have to go through the process of retraining?

Mr. Park. Well, as a matter of fact, in order to retrain, one of the things that industry does is turn back to the universities. The University of Maryland right now has an instructional television arrangement with Fairchild Industries in which we teach classes right at Fairchild via television.

And so some of the retraining is done now, and that collaboration with Fairchild has been extremely useful. In return, they have provided us with scholarships. They certainly pay a fee. And it has been, I think, an excellent program. I think they are happy with it.

Senator **Schmitt**. Do you think that is the kind of thing that is generally being done nationally, or is it a special circumstance?

Mr. **Park**. I do not know how widespread that is. I think it is growing. Certainly I know colleagues at other universities that have been involved in similar sorts of things, ordinarily where the university is located in an area which is a high technology area.

Senator **Schmitt**. Dr. Park, we appreciate your information this morning and we will see if we cannot find a solution somewhere along the line.

Mr. **Park**. Thank you.

[The statement follows:]

STATEMENT OF DR. ROBERT L. PARK, PROFESSOR AND CHAIRMAN, DEPARTMENT OF PHYSICS AND ASTRONOMY, UNIVERSITY OF MARYLAND

Mr. Chairman: My name is Robert Park. I am Chairman of the Department of Physics and Astronomy of the University of Maryland and a working scientist actively engaged in research.

A university has the responsibility not only to convey to each generation the sum of man's accumulated knowledge: it must also instruct in the very means by which knowledge is extended. This is accomplished by confronting real problems at the limits of our understanding. Progress in science has been marked by development of ever more complicated and powerful tools for understanding natural phenomena, which can then be turned to serve man. But these tools which contribute so much to the productivity of our nation and its technical enterprise are not cheap. Indeed the burden on the universities would be intolerable, were it not borne largely by public agencies in the expectation of benefits to society. Today, more than half of all basic research in the United States is done in universities and is supported overwhelmingly by the federal government.

This university-government collaboration has helped to maintain the United States in a position of technological leadership for over four decades, but we must remain alert to any symptoms of degenerative disease if we are to maintain that leadership in the face of continued challenge.

I appreciate the opportunity that has been afforded to me to discuss one such sympton: namely the declining state of research instrumentation in American universities. You have heard previous testimony concerning the circumstances that have led to the present problem and estimates of the accumulated need in dollars. Whether that need is $1 billion or $4 billion is not, I think, what should concern us here. It is unrealistic to suppose that either sum of money could be made available under present circumstances. What, then, can be done?

On March 12 and 13 of this year an *ad hoc* working group on scientific instrumentation assembled at the National Academy of Sciences to consider this problem. The group consisted of leaders of industrial R&D laboratories, representatives of various government agencies concerned with the problem, and university researchers. It was led by William A. Fowler, who has testified on this subject on the House side. The focus of the meeting was on instrumentation in the $50,000 to $1 million range in chemistry, physics, related areas of astronomy, and the life and earth sciences.

I was struck by the unanimity of the consensus that the problem of research instrumentation in universities seriously threatens the health of the scientific enterprise in the United States—in the short term by its direct impact on scientific research and in the long term by its effect on the training of scientists. The participants agreed that the problem was well documented and so spent the meeting discussing ways to ameliorate the problem within existing budgetary constraints. This Committee has a first draft of the report of that meeting, including the executive summary. Let me, then, if I may, comment on those aspects of the problem discussed during the NAS meeting that appear to me to be most serious. I will add a few words of caution about some of the proposed solutions, lest new problems be created in the act of solving the old.

1. *Block Funding*.—I believe the most serious challenge is to provide equipment for new faculty and for established faculty who wish to undertake major changes in

the direction of their research programs. Such changes are a measure of progress. It is inevitable that if we solve problems, the equipment designed to effect those solutions becomes obsolete. We must not cling to stale or outmoded research programs simply because we lack the resources to move on to areas of current concern. I believe the most straightforward way to address this problem is to provide block funding to institutions that can be used flexibly to provide instrumentation.

As a science administrator, however, I recognize the problem inherent in this approach. There is enormous pressure in the administration of flexible funds to provide help primarily to those who have difficulty in obtaining support from other sources. This often results in such funding being dissipated on second-rate researchers. There is therefore a need for safeguards, such as an annual peer review of the uses made of such blockfunding.

2. *Debt financing.*—There was much discussion of creative financing techniques during the NAS meeting. By this I refer to such approaches as overcoming the obstacles to capital acquisition presented by the grant system through leasing equipment from third parties. Anyone who has been living on a faculty salary these past few years has some gut feeling for debt financing, but it is an unfamiliar concept for University administrators. Universities must, however, be willing to use these techniques for the acquisition of major items of instrumentation. Such arrangements enable instrumentation to be financed either through direct-use charges against the grants or by inclusion in the indirect cost pool used in computing the overhead. This enables the institution to get equipment quickly. But no new money is created and the cost may ultimately appear somewhere else in the research program. A possible consequence of this type of financing will be to shift the instrumentation problem from major items of equipment to items of a few thousand dollars.

3. *Central Facilities.*—It has been suggested that the problem of scientific instrumentation in the universities could be alleviated by greater reliance on centralized research facilities utilized by a number of institutions in a given geographical area. It should be noted that the concept of jointly used facilities is firmly established in fields of physics requiring instrumentation of very high cost, such as high-energy particle accelerators and synchroton-light sources. When instrumentation of such high capital cost is involved, there is no alternative to centralized research facilities. The question, then, is whether this same principle should be extended to less costly facilities. Here I would urge great caution. Almost by definition the frontiers of knowledge cannot be moved appreciably with standardized commercial instruments. On the contrary, fundamental advances in knowledge are made with one-of-a-kind instruments, although the support of many standard analytical instruments may be required. As regional instrumentation facilities are developed, there is a tendency to distort research objectives to fit the instruments available.

A second serious concern with increased reliance on central facilities has to do with the effect on training graduate students. An important aspect of that training has to do with the interaction between graduate students, particularly across disciplinary lines. Reliance on centralized facilities tends to limit the experience of the graduate student to people working in areas closely related to his own.

The NAS Workshop concluded with a meeting of an industrial caucus and a university caucus. The former was led by George Pake, Vice President for Research of the Xerox Corporation, which has invested a substantial part of its corporate resources in upgrading the Nation's technology base. I led the university caucus. My academic colleagues were impressed by the rational approach of their industrial colleagues in managing research and were open to seeking ways to promote better management of resources and to facilitate planning for a reasonable balance between manpower and capital acquisitions. We agreed that a series of regional tutorial workshops, held across the country, could do much to encourage the academic community to take an active role in solving this problem. These workshops would bring together on a local scale industrial research leaders, university researchers, and scientists from federally funded laboratories. I hope that continued discussion among those three elements of the U.S. scientific enterprise can work to the mutual benefit of all three sectors in solving this fundamental problem.

The emphasis of the NAS Workshop was on seeking solutions within "existing budgetary constraints." Certainly we must make every effort to manage our resources efficiently. This is, however, only part of the problem. I have worked in both corporate and government laboratories. In my view, universities do not do all that bad a job of management. Without new money we are simply going to push the problem from one place to another.

Quite frankly we will always need more money. The challenges and prospects we face are so great that we will never have enough. But the challenge the U.S. faces right now is to its technological leadership. That leadership has been challenged repeatedly in the last 40 years, and each time government, industry and university have worked together to meet and overcome the challenge. We must do the same now.

Senator SCHMITT. Thank you. Our next witness, Dr. F. Thomas Juster, director, Institute for Social Research at the University of Michigan, Ann Arbor. He is representing the Consortium of Social Science Associations.

Doctor, welcome. And as with the other witnesses, if you wish to summarize your testimony, I hope you will and then we can get to a few questions. It will be included in the record in its entirety without objection.

STATEMENT OF F. THOMAS JUSTER, DIRECTOR, INSTITUTE FOR SOCIAL RESEARCH, UNIVERSITY OF MICHIGAN, REPRESENTING CONSORTIUM OF SOCIAL SCIENCE ASSOCIATIONS

Mr. JUSTER. Thank you, Senator. I would like to spend——

Senator SCHMITT. Did I pronounce your last name right? I spent some time in Norway and I am always on the verge of pronouncing the "J" correctly.

Mr. JUSTER. "J" is correct. I would like to summarize the statement just briefly. I make four points in it which I think are equally important ones.

One is that in this environment, investments in knowledge, generally investments in R. & D., are as important as investments in conventional kinds of things like factory buildings and machines for productivity purposes. Secondly, investments in knowledge about the functioning of society and the economy, which is what social scientists do, are fully as important and have fully as much priority as investments in knowledge about engineering, physics, chemistry and the natural sciences; third, at the present and recommended funding levels for social, behavioral, and economic sciences there are a large number of important ongoing programs which cannot be accommodated. And fourth, perhaps even more importantly, there is an agenda of activities which would usefully be done which have important pragmatic and scientific payoffs, and they cannot be accommodated, either.

Let me note briefly the nature of what society gets for investments in social, economic, and behavioral sciences. It is rather different in the social sciences, I believe, than in the natural sciences. In the private sector, the returns to social science research, as far as I can tell, are largely embodied in the training and skills of people that staff various kinds of business organizations—corporate strategic planning groups, financial planning groups, marketing groups and firms that are in the consulting business.

What happens is that these people acquire skills. They then use them, along with social science concepts and tools—economic modeling, systems analysis, personnel testing, market research and so forth—as an aid to business decisionmaking. Once in a while, there is a rather more direct use in the private sector.

An interesting recent illustration of more direct use is an interest on the part of the pharmaceutical manufacturing industry to try to use the findings of quality-of-life research to assess the contribution of pharmaceutical intervention to the health and wellbeing, in the long-term sense, of the U.S. population.

I see the principal returns to basic social science research as in the provision of a basic framework of information and analytic insight that has helped us to understand how our economy and society actually work. Social scientists contribute a critical assessment of ideas about how to make the economy and society work better. They substitute fact and tested theory for myths and stereotypes, and they provide insights into the characteristics of important social and economic problems such as inflation, productivity, crime, population change and so forth.

I think that the subcommittee should pay particular attention to the role of information and data in the social science programs funded at the National Science Foundation. Information about society and the economy provides an essential background for any informed discussion about policy or the consequences of a policy change.

Moreover, a carefully designed information base is an indispensable ingredient for the development and refinement of theoretical and conceptual structure. And finally, well-designed scientific data bases, especially those that have longitudinal characteristics, offer the best prospects for achieving a base of solid and reproducible social science knowledge.

I would also like to note a couple of important characteristics of the NSF program which is targeted on development of these scientific data bases. First, these programs require substantial and sustained resources, relative to the typical analytical project which comes in smaller pieces and may not extend beyond 2 or 3 years. As an illustration, one such project at my own institution costs a total of about $1.5 million annually, and its useful duration extends for at least another decade.

Secondly, these projects are the natural focal point for sustained interdisciplinary and team-oriented research or activities. And finally, these large continuing measurement-oriented programs have the capacity to change the face of scientific understanding in a way that smaller scale and more isolated activities, however meritorious, do not. You will, of course, recognize that the scientific data base projects are in many respects the social science counterparts of support for the national laboratory facilities in the natural sciences.

Now, let me turn briefly to summarize the budget recommendations. Let me begin by providing some quantitative perspective on the social and behavioral science programs at the NSF.

Of the total number of scientists in the United States about a third are social scientists. Of the total number of scientific problems worth putting resources into, where resolution would eventually improve the conditions of people in society, perhaps about the same fraction, a third, might be social and behavioral problems. But of the total resources available to the NSF for scientific inquiry, the social and behavioral sciences are recommended for roughly 3 percent instead of a third of the total. Down from about 5 percent 2 years ago.

In my judgment, that recommendation represents a severe misallocation of scientific resources. It provides just about half the amount of resources in real terms as were available in 1980 and is the direct result of the disproportionate cuts first proposed by the administration over a year ago.

It is now widely acknowledged that the severe cuts proposed for the social and behavioral sciences were, to quote Mr. Keyworth, the President's science adviser "poor judgment."

On scientific quality, the Director of the NSF, Dr. Slaughter, has said this year in congressional testimony that the quality of NSF's social science research is fully equal to the quality of its natural science program. And the most recent NSF study of the quality of research in the social and behavioral sciences conducted in the middle seventies, came to the conclusion that the quality of social science projects was at least as high as the quality of it's natural science programs.

Let me note the kinds of activities that the budget recommendation will not be able to accommodate. A large set of programs concerned with development of social science longitudinal data, bases which have already been approved by the scientific review process within the NSF, cannot be accommodated. Three of them can operate at levels consistent with the collection of new information, but the information levels are suboptimal; the other projects are in a hold pattern.

To illustrate, the budget will not accommodate the collection of annual data for the general social survey which assesses social trends in the U.S. population; or in the time use of American households, which permits current analyses of the underground economy, of volunteer activity and of changes in labor productivity based on reliable estimates of time spent at work; or expansion of the environmental data base; or the collection of new data on the perceived quality of life among American households. And it severely inhibits the creation of public use files from governmental archives.

I can make the same statements about programs in the area of theory, methodology and new initiatives. The available resources require either rejection or sharp curtailment of a substantial amount of the highest quality proposed research.

Finally, there is a large agenda of potential research activities where substantial payoff is both possible and likely but which are simply not feasible. I note some in my testimony and I will simply list them—savings behavior, where we need to understand the way in which people save or change saving as they age, health behavior, productivity of the firm, technology, organizational structure, and analysis of how people respond to uncertainty—these represent major possible initiatives which cannot be accommodated within the present budget.

Let me sum up very briefly. I would urge the subcommittee to restore funding in the social behavioral sciences to fiscal year 1980 levels. That requires adding approximately $18 million, less than 2 percent of the present NSF budget, to the biological, behavioral and social sciences directorate, earmarked for the social, and behavioral science programs.

One could get these resources either by some modest redirection of increases in the NSF research budget or by adding to the budget totals. My own preference would be to add resources. I view this as a time in our society when we need to invest in a variety of things, including basic knowledge, and that would clearly be my preference. If that is not possible, I would argue strongly for redirection of the increases as the best way to allocate the existing budgetary amount within the National Science Foundation budget.

Thank you, Mr. Chairman.

Senator SCHMITT. Thank you, sir. And that is an impressive list that you have in your testimony. I agree with you. We are operating pretty much in the dark when we try to make public policy in those areas. That does not mean we do not try to make and do make it, right or wrong, but we are operating pretty much in the dark, maybe only with whatever commonsense our own experiences have provided us.

Doctor, do you see any potential for industry to provide funds leveraged by the NSF dollars, matching or other types of programs?

Mr. JUSTER. I believe there is some potential. My sense of it is that it would vary somewhat with the social science area. It would matter which area you were talking about. Let me illustrate in a couple of areas where I think leveraging is possible and a couple where I think it is less likely.

We have presently at the Institute for social research a program of work in what we call organizational behavior. A major focus of that activity is to attempt to put to use what you might probably call human factors analyses, within the context of the organizational structure of the firm. Much of the funding for that already comes from the private sector.

What happens there is that private sector firms discover that they have an organizational problem, and will ask our people to formulate a project designed to assess the problem. We also have funding in that area from the public sector.

Now, in an area like that where the private sector firm can see a rather direct payoff, I think leveraging of NSF funds has an enormous potential and would make it very much more attractive. The same is probably true in certain areas of economic research.

Senator SCHMITT. Such as savings behavior?

Mr. JUSTER. I think that savings behavior is a good case in point. Of course, you have to keep in mind that the firm or industry has to see something in the nature of a direct payoff to them within a reasonably short time period. A private sector firm cannot justify investment in something which will make the society function better in 10 years and then give them some benefits in 20. They simply will not do because their payoff horizons are too short.

Senator SCHMITT. Savings behavior is based on interest rates and——

Mr. JUSTER. If you ask me where you might find private sector support for studies of savings behavior, it would be firms in the financial services sector—American Express for example, and in the banking industry. They have an active concern about where savings dollars are going to be held, and some of their interest in where the dollars are going to be held might be matched by some of our interest in how much total saving there is going to be.

So I think there are areas where a public—private match is possible. If you turn to areas like political science and anthropology and perhaps sociology, my guess is that the private sector firms will look at that and say yes, we certainly would like to see some-one doing important things there, but we can't justify support. They do not see any way in which they directly receive a return that would justify the activity to their stockholders.

Senator **Schmitt**. Doctor, I have had the impression, right or wrong, since we started getting into this, that the social sciences are in an historical position comparable to that which was occupied by the geological sciences in the 1930's and 1940's, the medical sciences in the 1920's, maybe, in that the number of variables you have so greatly exceeds the number of equations that you are still in the business largely of collecting data and making observations and trying to get to the point where some basic theories can be proposed that will pull a sufficient number of equations together and eliminate a sufficient number of unimportant variables, so that you can actually solve problems.

That has happened in other sciences in the past and I strongly believe it will happen in the social sciences. Would you agree that you are at that stage? I call your attention to your testimony and wonder whether your second point is not really the highest priority in the social sciences, not to say that the others are not important. Aren't we still dealing with an inadequate base of information or observational data in the social sciences to really come to any basic decisions?

Mr. **Juster**. I would agree with that judgment. I should warn you that a substantial number of my colleagues probably would not.

I happen to be the director of an institution whose main reason for existence, and whose distinguishing feature, is a judgment that data about behavior is what we lack most. That is, in general, what most of us do out there. And the reason we take that view is that we are persuaded that the only way we can make progress is to expose theory to relevant data.

How much resources are worth putting into scientific areas is, to some extent, an issue of the age or maturity of a discipline. Social sciences, with the possible exception of economics, are relatively young disciplines. Economics is a couple of centuries old.

It is also certainly my perception that the thing we lack most is the ability to discriminate between competing explanations of behavioral phenomena, and there is no way that you can solve that problem with elegant models. You have to solve it by forcing models to have their noses rubbed against some data. To do it you have to have some data, it has to be the right data and it unfortunately cannot often be data which happened to be available because a Government administrative agency decided they wanted to collect some information about something.

That is one of the problems, as I see it, in the social sciences. Our tradition, because data collection is expensive and resources are scarce, is to try to adapt data from the Census Bureau, from the Bureau of Labor Statistics, from voting records, from this and from that, to try to adapt those data to confront theories. And the trouble is the data are often not quite adequate and you are left with ambiguity.

Generating the right kind of data base to form a definitive test of a theoretical structure or competing structures is expensive. Cumulatively, it has enormous payoff because then you finally do know something that is solid, instead of problematic, and it is something that people cannot really quarrel with.

So, yes, I would say that significant attention paid to the development of scientific data bases and to the measurement process and to the confrontation of theory with data is a very important priority from my perspective—the most important. As I said, other people would not agree with that.

Having said that, I think one cannot ignore the fact that you cannot just do one kind of activity. You must devote resources to theorizing and conceptualizing. You must devote resources to estimation. You must devote resources to the development of new and risky ideas and people. You cannot kill your seed corn—shutting off younger investigators with ideas they want to develop. So you have to have a balance.

I think the most progress from my perspective will come from the kind of resources invested in data bases, especially ones which are longitudinal. They have special advantages, but also have especially heavy costs.

Senator **Schmitt**. Well, there is no indication of which I am aware that maturity is based on the number of years the science has been recognized. I think, more accurately, that it is based on having a sufficient data base, as you call it, in order to begin to generalize, to begin to have the ability to test theoretical models against, as you say, the real world.

That does not mean that you ignore the other aspects, but you have to recognize your level of maturity and proceed from there to justify the level of expenditures. It does not mean necessarily that the level is any less, because it is often more difficult to collect the statistical base.

But it is harder to justify to your peers or the Congress because it is hard to show definitive results at this level of maturity of the science, even though it is a phase through which you have to go in order to get to that point where you can show very specific and direct applications of your data.

Mr. **Juster**. I would not quite agree with your proposition—I think we are at a somewhat earlier stage than you do.

Senator **Schmitt**. Maybe it is a transition stage, but you are not where physics got to a couple of decades ago, where the Earth sciences and the biosciences have arrived more recently. You are just not quite there yet—and it is tougher to justify the budget. Not that they are not justifiable; it is just tougher to do.

Mr. **Juster**. I do think it is important to keep in mind that in terms of capacity for analysis, and the availability of analytic techniques to do an effective job of finding what one can extract from the data in terms of testing hypotheses, there are important anayltical techniques whose development is no more than two decades old. I refer to the power of computing systems and the access to software and hardware, which makes it possible to take masses of data and process them in complex ways at relatively low cost.

When I started out in this business, we used to do things by running cards through a card sorter. You cannot do sophisticated analyses running cards through a card sorter. That was only three decades ago. It was only from the middle 1960's or early 1960's that you really begin to have the kind of computing power and software where a lot of social scientists had ready access to the massive computing power needed to force hypotheses into confrontation with the data.

It is a very recent development, and I think we have made a great deal of progress because of it. But that is a very recent development, and one expects knowledge to accrete slowly. On the whole, we have done pretty well—not as well as one would like, but given the fact that such analytic capacity has existed for only two or two and a half decades, not too badly.

Senator SCHMITT. Well, as a former icepick sorter of data, I understand what you are talking about. For those who do not know what that means, we used to punch holes in cards for particular types of data. Then you put an icepick through the stack and lifted out the cards that covered a particular area. It was quite sophisticated in its time.

Mr. JUSTER. But you do not do multivariate analysis that way.

Senator SCHMITT. No, you don't. Doctor, we are going to have to move on. Thank you very much.

Mr. JUSTER. Thank you very much.

Senator SCHMITT. Our next witnesses will appear together as a panel. Dr. Franklin Lindsay, chairman, ITEK Corp. He is representing the National Engineering Action Conference, and the Committee for Economic Development. Dr. Francis E. Reese, senior vice president, Monsanto Co., is representing the National Society of Professional Engineers as chairman of the Industrial Advisory Group.

Gentlemen, I appreciate your patience. We are roughly on schedule—15 minutes behind in this game is not too bad. Mr. Lindsay, is it doctor or mister?

Mr. LINDSAY. Mister.

Senator SCHMITT. Mr. Lindsay, if you would proceed to summarize your testimony, it will be included in the record in its entirety. And then Dr. Reese will be next with the same constraints.

STATEMENTS OF FRANKLIN A. LINDSAY, NATIONAL ENGINEERING ACTION CONFERENCE, COMMITTEE FOR ECONOMIC DEVELOPMENT; AND FRANCIS E. REESE, NATIONAL SOCIETY OF PROFESSIONAL ENGINEERS, AS CHAIRMAN, INDUSTRY ADVISORY GROUP

Mr. LINDSAY. Well, having heard the discussion this morning, and particularly, of your own statement, I think there is complete agreement on the nature of the problem between you on the one hand and the Committee of Economic Development, and the National Engineering Action Conference. So I will skip anything in our written testimony dealing with that.

Let me turn to the more specific problems of education of engineers in this country. I would like to outline the views of the National Engineering Action Conference. The conference is a nonpartisan group that brings together national leaders from every sector of society concerned with engineering.

The conference's goal is to identify and promote actions to meet the shortage of engineering faculty and the even worse shortage of doctoral candidates preparing for teaching careers.

The conference believes that no single sector of society has the resources or the wisdom needed to solve the problems of educating engineers. Accordingly, on April 7, a meeting sponsored by the National Engineering Action Conference drew participation from the four sectors with the greatest capacity to act on the problem: Higher education, industry, professional groups, and Government. Most of the recommendations are directed toward nongovernmental institutions.

It is clear that industry and the universities must work together to increase the incentives, rewards, and recognition for undergraduate engineering teaching. This means higher salaries for faculty and increased stipends to attract high caliber graduate students. But private funds cannot pick up the entire costs that are being reduced in Government funding.

I would like to take a minute to just briefly describe a new—I guess what one might call invention—in industry: cooperation with the universities, and one with which I am personally involved. I believe it has a great potential for aiding science and engineering education. Very briefly in this case, six major companies are currently funding university research through a nonprofit organization and have made equity investments in a new for-profit company.

The nonprofit organization, the Center for Biotechnology Research, holds 30 percent of the equity of Engenics, Inc. a before-profit company, and the charter of the center provides that any resultant income, either capital gains or dividends, can only be used to support further university research.

Thus, for the first time, universities will share significantly and from the beginning in the success of an enterprise that has drawn its technology from basic research in university laboratories. Yet, the universities are not direct shareholders, and any appearance of conflict of interest because of faculty involvement is avoided. And if you are interested, I would be glad to talk a little further about that.

However, Mr. Chairman, the Federal Government, too, has a role to play in engineering education. The conference recommends that the National Science Foundation, Federal laboratories, and other public agencies continue to support study for engineering doctorates in preparation for teaching careers. This can be done through carefully targeted funds for fellowships, traineeships, internships, and other aids. The budgets for these activities must necessarily reflect the President's belt-tightening program, although our economy and our national security benefit many times over from increased support for engineering and technology.

I think the return on investment in engineering and in people is, by and large, very much higher than the return on investment in plant and equipment.

The Government has provided incentives for that type of—for the former investments of inplant equipment, and I believe must continue to supply investment in very high-yield, these other investments.

I think I will simply stop at that point, Mr. Chairman, and respond to any questions you may have.

Senator SCHMITT. Your entire testimony is very helpful, and will be included in the record without objection.

[The statement follows:]

STATEMENT OF FRANKLIN A. LINDSAY, CHAIRMAN, RESEARCH AND POLICY COMMITTEE, COMMITTEE FOR ECONOMIC DEVELOPMENT AND CHAIRMAN, EXECUTIVE COMMITTEE, ITEK CORP.

Mr. Chairman, my name is Franklin A. Lindsay. I am chairman of the executive committee of Itek Corporation, a high-technology company based in Lexington, Massachusets. I am also chairman of the Research and Policy Committee of the Committee for Economic Development. CED was formed in 1942, and it continues today as a private, nonprofit, public policy organization of 200 leading corporate executives and university presidents. Its mission is to build consensus on some of the critical issues facing our nation and our economy, and to communicate solutions to leaders in government, business, education, and the media.

Mr. Chairman, I am today representing both the Committee for Economic Development and the National Engineering Action Conference on the key issue: How can we improve engineering education in the United States today? We must find answers to this question, and very quickly. President Reagan stated it very well in his message to the Conference: "The preservation and growth of this resource is essential to a healthy economy and to the national security."

The threat to the quality of engineering education is a very serious one. More than 1,600 engineering faculty positions—or some ten percent of all such teaching positions in the United States—are unfilled today. Almost half of these 1,600 jobs have been open for a year or more. Even if all of the nation's 1981 engineering doctoral students entered teaching, this gap would not be closed.

Meanwhile, rising demand and high salaries for engineers in private industry have sparked record enrollments of undergraduate engineering students. The 1980 freshman class in engineering programs numbered 110,000. Total undergraduate enrollment in these programs was 365,000 in 1980, a 58 percent increase in only five years.

Very simply, Mr. Chairman, we have an overwhelming number of engineering students, for whom our nation and economy have a great need, and too few teachers to teach them.

The result is a serious bottleneck in engineering education. We are seeing overcrowded classrooms, restrictions on spending for instruments and equipment, and worst of all—a trend by major universities to limit enrollment and freeze funding for engineering education.

This bottleneck is real and it is potentially tragic for this nation. The quality of instruction in engineering is headed down. This is not just my opinion. It is the view of over 80 percent of engineering deans in a recent survey. As this quality deteriorates, so must the capacity of the United States to maintain its world leadership in technology and innovation.

The future quality of our lives is directly tied to the nation's scientific and technological progress. In a world with a growing population, rising social and economic expectations, and declining renewable resources, our ultimate resources are science, technology and engineering. I agree with the scientist Philip Handler who said that these are the principal tools "that our civilization has developed to mitigate the condition of man."

TECHNOLOGY: A KEY LONG-TERM ISSUE

Over the years, the Committee for Economic Development has recommended improvements in our educational system, recognizing that education provides the human capital needed by our economy and our society. CED has also clearly demonstrated how much technology and innovation contribute to the productivity and competitiveness of American industry.

These concerns were highlighted in an influential 1980 CED policy statement called Stimulating Technological Progress. CED said in that statment that "there is strong evidence that technological progress is perhaps the most important source of future economic vitality and social progress for the United States." In recent years, according to some estimates, as much as one-half of the growth in real per capita incomes—and they have gone up 65 percent since 1945—can be attributed to technological advance.

The CED report made clear that the private sector is best equipped to develop technological and scientific breakthroughs, and it recommended a package of measures that included faster depreciation of plant and equipment, more flexible depreciation allowances for research and development facilities, and reduced capital gains and maximum marginal tax rates to spur high-risk investment and innovation. All of these measures, as you are well aware, Mr. Chairman, were part of the 1981 tax reform legislation, and CED trustees are confident that increased research and development to improve products and processes will occur.

CED argued in the same 1980 report for a public-private partnership to ensure adequate support for basic research. We said then:

"There is a strong and intimate connection between the conduct of basic research and the education of scientists and engineers. Such talent, with the ideas it embodies, is a major national resource; we believe, therefore, that it is justifiable for the country at large to pay some portion of the cost of developing that talent through the financing of basic research work in the universities."

Mr. Chairman, a steady rate of technological progress and the continued health of our engineering educational system go hand in hand. Both are critical to the nation's future. Virtually the entire spectrum of public policy issues we face—from health to housing, from energy to the environment, from transportation to education, and many others—all of these depend for their solution at least in part on technological and engineering knowhow. Gerald Holton, the noted Harvard University physicist, estimates that well over half of all national policy decisions are scientific or technical in nature. In my view, this percentage can only grow in the coming years and decades.

ENGINEERING EDUCATION IS VITAL TO THE UNITED STATES

Let me turn now to the more specific problems of the education of engineers in this country. If I may, I would like to outline the views of the National Engineering Action Conference. NEAC is a nonpartisan group that brings together national leaders from every sector of society concerned with engineering. The Conference's goal is to identify and promote actions to meet the shortage of engineering faculty and the even worse shortage of doctoral candidates preparing for teaching careers.

CED is pleased to be a paticipating organization with NEAC, for just as CED advocates cooperative public-private approaches to addressing the nation's economic ills, so does the NEAC believe that no single sector of society has the resources or insight needed to solve the problems of educating engineers. Accordingly, an April 7 meeting sponsored by the National Engineering Action Conference drew participation from the four sectors with the greatest capacity to act on the problem—higher education, industry, professional groups, and government. The 50 participants at that meeting adopted a series of proposals for action. Mr. Chairman, with your permission, I would like to submit these for the record.

Most of the recommendations are directed toward non-governmental institutions. It is clear that industry and the universities must work together to increase the incentives, rewards and recognition for undergraduate engineering teaching. This means higher salaries for faculty and increased stipends to attract high-caliber graduate students. A unique private-sector initiative toward these ends is the $16.8 million program of the Exxon Education Foundation, which provides for 100 doctoral fellowships, 100 junior faculty assistance grants, and targeted aid to six historically black engineering institutions.

NEAC also urges business-education partnerships to give graduate students experience in industrial research and to increase spending on instruments and research equipment in the universities. We are confident that these and related proposals will receive favorable consideration by the private sector.

There is another vehicle, one with which I am personally involved, which may have great potential for aiding science and engineering education. Very briefly, six major companies are currently funding university research through a non-profit organization, and have made equity investments in a new, for-profit company. The non-profit organization, the Center for Biotechnology Research, holds 30% of the equity of Engenics, Inc., the for-profit company. And the charter of the Center provides that any resultant income, either capital gains or dividends, can only be used to support further university research. Thus for the first time universities can share significantly, and from the beginning, in the successes of an enterprise that has drawn its technology from basic research in university laboratories. Yet universities are not direct shareholders, and any appearance of conflict of interest because of faculty involvement is avoided.

However, Mr. Chairman, the federal government, too, has a role to play in engineering education. Indeed, the National Science Foundation does a praiseworthy job in this respect. NEAC recommends that the Foundation, federal laboratories, and other appropriate public agencies continue to encourage study for engineering doctorates and preparation for teaching careers. This can be done through carefully targeted funds for fellowships, traineeships, internships, and other aid. The budgets for these activities must necessarily reflect the President's belt-tightening program, although as I have already pointed out, our economy and our national security benefit many times over from increased support for engineering and technology.

Let me suggest another way that the federal government can led assistance. The Committee for Economic Development as long urged public-private partnerships to meet a variety of national needs. My colleagues in the business community have become increasingly concerned that investment in education and training, geared to the long-term needs of employers and the economy as a whole, is at pitifully low levels. CED has two studies underway that will consider the implications of low human capital investment for U.S. competitiveness in global markets and for our productivity performance.

Mr. Chairman, engineering education needs its own set of human investment policies. That is abundantly clear from all the information available to us. Such po[illegible]s need not require new federal dollars in large amounts. But what the federal government must do, to the extent possible, is facilitate private sector action to address this issue.

For example, the federal government has in recent years leveraged some grants to urban areas by requiring comparable private investment, sometimes dollar for dollar. It seems to me that the same principle might be applied to policy toward engineering education. The National Science Foundation would be an excellent agency to administer such a matching program.

Let me conclude with a final thought. We face today a serious shortage of engineering faculty, and there is the prospect of an eventual shortage of engineers because of it. Engineering is a skill that is critical to the United States, for the meany reasons I have mentioned. While this country graduates only 60,000 engineers a year, Japan graduates about 73,000 and the Soviet Union, 300,000 each year!

This is a real problem, and the federal government needs a policy that addresses it. The National Engineering Action Conference strongly urges that the National Science Foundation be permitted to continue its porograms to support the training of engineers and engineering teachers. At the same time, this Subcommittee should consider ways to target and leverage that federal support so that the private sector has the incentive to do its share, as we are confident it will.

A workable human resource policy aimed at improving engineering education will have enormous economic and national security payoffs in this and future decades.

Thank you, Mr. Chairman, for the opportunity to appear before this Subcommittee.

Senator SCHMITT. With respect to the Center for Biotechnology Research, was that stimulated by the passage of the university and small business patents legislation?

Mr. LINDSAY. No, it was not. We put this together before it happened.

Senator SCHMITT. But it will help, right?

Mr. LINDSAY. Our hope is it will help in the future. I guess my own feeling over the years of having been in a high technology company at ITEK was that from time to time, we acquired high technology companies where the founders had come out of universities. They had taken their technology with them. They essentially—everything they were, at least in an economic sense, was due to what they learned at the universities, and it always seemed to me that there ought to be a way for them to bring the universities in on the ground floor.

I think we have found it in a way that does not result in conflict of interest between the faculties and the universities. If the universities were direct shareholders in new enterprises that come out of their laboratories, at least they feel and I would agree there are some real problems. But we are currently funding Ph. D. training. We are funding equipment in these programs, and post-doctoral fellowships. So that—and in the longer run, if we are successful or if this formula is copied, some companies are bound to be successful.

And I think the return, if one simply thinks of, for example, a Hewlett Packard which came out of Stanford University's laboratories, if today through a nonprofit organization, 30 percent of that extremely successful corporation were owned beneficially by the universities through an intermediary nonprofit, it would do a great deal to help.

We also provided in the charter of this nonprofit, that the trustees do not have to put the money back into the same technology nor do they necessarily have to invest in the same universities. Ten years from now the needs may be in another field.

Senator SCHMITT. Dr. Reese?

Mr. REESE. Thank you. I think first of all I thank the committee for gratuitously giving me a doctorate. Recognizing your own accomplishment, I am also a mister.

Senator SCHMITT. Well, we will have to change the sign in front of you there.

Mr. REESE. I do appreciate the opportunity to testify this morning on issues relating to the National Science Foundation's fiscal year 1983 authorization. I am representing the National Society of Professional Engineers, as chairman of that organization's industry advisory group.

The National Society of Professional Engineers represents some 80,000 members nationwide including practicing engineers in every aspect of the profession. The industry advisory group consists of senior executives having engineering responsibilities from a variety of technology intensive industries. I am also representing Monsanto where I am a senior vice president.

The National Science Foundation certainly plays an important role in the Federal Government's efforts to improve academic research in education, in science and in engineering. Yet, despite the Government's continuing role, and despite efforts by American industries and universities—and I suggest indeed, industry is diligently working on this problem despite the fact that clearly this morning there are several people who think we might do more—the United States faces major problems in this area.

There is concern in the business community over the quality of engineering and other scientific education being provided by our universities, and over shortages in the supply of engineers.

There is an awful lot of discussion on this matter, the shortage of engineers. It is not a clear-cut issue. I frankly do not believe it is accurate to say that we face a universal shortage of engineers throughout the profession. There clearly are not enough trained personnel to meet the demands of business and industry in certain specialties in certain geographic areas.

However, of equal or greater concern throughout the profession is the quality of education being received by students at our universities. If we hope to produce first-class engineers, we must have first-class faculty, first-class graduate research programs and modern, updated facilities.

I strongly believe we need a combined Government-academe-industry effort to address this problem.

Our engineering schools, as has been suggested earlier today, are struggling to attract and retain qualified faculty. But again, because bachelor degree holders in engineering can command higher salaries by working in private industry than by pursuing advanced degrees and careers in teaching, an estimated 1,600 engineering faculty positions currently are open. The number suggested earlier in terms of shortages in New Mexico universities I think are almost double the figures for the Nation as a whole.

With faculty resources stretched thin and with many students showing a reluctance to pursue advanced degrees, our graduate programs and the fundamental research efforts in academe are suffering, and this compounds the problem by making graduate level education less attractive to those students who might be inclined to seek it.

And finally, again as suggested earlier, our universities are operated with aging, often outdated equipment. It is not uncommon, for example, to find in electrical engineering schools laboratory facilities that are dominated by electromechanical devices, despite the fact that solid state gear today obviously represents the state of the art.

Now, with tight university budgets being a fact of life, expenditures for equipment do tend to rank low on the totem pole. It is difficult, though, to comprehend how we can maintain a leadership role in cutting edge technology if our future engineers and scientists are being educated utilizing outmoded facilities.

It seems to me, as a society we must make certain that our universities have the resources to carry out that role—to train innovative and creative engineers and scientists, and carry out leading edge fundamental research in a variety of sciences important to mankind. Those resources include both faculty and physical assets.

I do not suggest that this challenge is just the Government's problem. The Federal and State Governments certainly have important roles to play, but the private sector must have a major responsibility. After all, business is the primary consumer of technical manpower.

The National Society of Professional Engineers strongly believes that the solution to this problem requires a joint public-private effort. An effective Government-industry program should allow us to expand and improve our university programs significantly without placing all the burden on the Federal treasury.

A cooperative effort will allow the public and private sectors to maximize the impacts of their investments. Therefore, I urge this subcommittee to give serious consideration to a matching grants program between industry and Government. If it is properly structured to make industry, Government and the acamdemic community partners, we should be able to best allocate our scarce dollars to the most pressing needs in the technology areas.

I would like to make two points concerning this proposal. First, it should be flexible. The scope of the projects eligible for funding should be wide so that the Government officials, university faculty and industry representatives can work together effectively to determine where the support is needed.

In this regard, grants should cover a broad range of research and technical education at our universities.

Senator SCHMITT. Including facilities?

Mr. REESE. Yes, sir. In particular, industries should have the opportunity to initiate grant proposals in cooperation with the university community. Business leaders do have a firsthand knowledge of where the problems exist, and they will be able to provide valuable ideas for making a matching grant program work.

Dr. Park I believe referred earlier to the Business Advisory Council that exists at many universities. I personally participate in one at the University of Texas, and also, I am active in one at Washington University. This is not uncommon. I believe there is a fair understanding of the problems on the part of the business community.

In fact, private industry is already active in this area. To provide you with one example to which you made reference in your opening comments—the Monsanto Co. is part of this organization called the Council for Chemical Research which was started 3 years ago as an idea, and now includes over 30 companies and over 120 universities.

It has been organized to bring together companies which employ chemists and chemical engineers, and to increase industry support for and interaction with higher education. Our efforts currently are aimed at improving graduate level programs in chemistry and chemical engineering. This is our first year of full operation, and our companies already have pledged $3.5 million per year of added support for a 3-year period.

In other words, these funds are in addition to our past levels of support, and are basically being funneled through the council as unrestricted funds.

And I might point out that this, again, does not necessarily represent, even for those 30 companies, the added support we are putting into university education. These are the funds that we are turning over to the council for allocation to the participating universities.

In the case of Monsanto, we currently are contributing more than $10 million per year in support of education at the university level through fellowships, grants, scholarships, and research contracts.

For U.S. industry as a whole it is difficult to come up with a number, but it certainly would appear that current levels of industrial support for engineering and science education are probably in excess of $300 million per year.

Now, in addition to that direct financial support, hundreds of companies across the country are purusing a variety of initiatives to aid colleges and universities in science, scientific, and engineering education. These projects include student cooperative programs, adjunct professor assignments where industrial representatives spend part time teaching on college campuses, frequently at company expenses, equipment donations, summer employment programs for both students and faculty, and programs to match gifts made by employees.

Now, it is true that these efforts can and will continue without Government involvement. We see these as being absolutely essential for maintaining the viability of our educational system. But I do believe that a partnership between Government and industry would allow us to increase the resources available to our universities via providing added incentives for academe to take initiatives on their own and providing an opportunity for the marketplace to have an input on the distribution of the funds.

I am aware that you have discussed the possibility of a matching grants program with Dr. Slaughter when he appeared before you on March 25, and I certainly would like to add my support to that idea and encourage consideration of it.

I do not come with a specific dollar figure to propose for such a program. In an issue as complex as this, the viewpoints and perceptions are many. Some estimates on the cost to correct faculty shortages in large graduate programs and to upgrade facilities have ranged as high as $1.5 billion.

My own view is that a quick fix is neither practical nor possible, and that the resources to be applied to the problem must come from a wide variety of directions, including industry, individuals, foundations, State, local, and Federal Government, and university fees and tuitions. In other words, it is a societal problem needing societal solutions.

I further believe that relatively modest funds with maximum flexibility in their application to the most pressing needs, which certainly are not common across the spectrum of public and private universities and colleges, could have a measurable impact on insuring our country's leadership in science and technology for the decades ahead.

In closing, I want to convey to you the National Society of Professional Engineers' strong support for a flexible matching grants program, and to offer you whatever assistance NSPE's membership and staff can provide in formulating such a proposal. As an organization representing professional engineers in industry, private practice, and academe, NSPE will be happy to provide to you and your staff information and recommendations as you so desire.

Again, Mr. Chairman, I appreciate the interest of you and your committee in this important issue. This concludes my prepared remarks, and I will be glad to answer any questions.

[The statement follows:]

STATEMENT OF FRANCIS E. REESE, P.E., CHAIRMAN, INDUSTRY ADVISORY GROUP, NATIONAL SOCIETY OF PROFESSIONAL ENGINEERS, SENIOR VICE PRESIDENT, MONSANTO CO.

Mr. Chairman, I appreciate having this opportunity to testify this morning on issues relating to the National Science Foundation's fiscal 1983 authorization. My name is Francis E. Reese, and I am here today representing the National Society of Professional Engineers (NSPE) as Chairman of that organization's Industry Advisory Group. The National Society of Professional engineers represents 80,000 members nationwide, including practicing engineers in every aspect of the profession. The Industry Advisory Group consists of senior executives having engineering responsibilites in major corporations from a wide variety of technology intensive industries. I am also representing Monsanto Company, where I am a Senior Vice President.

You and the Subcommittee are to be commended for your deep interest in maintaining and improving the many fine programs of the National Science Foundation. This organization plays an important role in the Federal Government's efforts to improve academic research and education in science and engineering.

While all agency budgets are under careful scrutiny during this time of fiscal restraint, it it encouraging that the Administration has recommended a 7.7 percent overall increase in the NSF budget in fiscal 1983. This action indicates that the

White House recognizes the importance of research, development, and technical education to the future prosperity of our economy.

Yet, despite the government's continuing role in national research and development, and despite efforts by America's industries and universities, the United States faces major problems in this area.

There is concern in the business community over the quality of engineering and other scientific education being provided by our universities and over shortages in the supply of engineers.

There is a great deal of discussion on the shortage of engineers, Mr. Chairman, and this is not a clear cut issue. While I do not believe it is accurate to say that we face a universal shortage of engineers throughout the profession, there clearly are not enough trained personnel to meet the demands of business and industry in certain specialties and in certain geographic areas.

However, of equal or greater concern throughout the profession is the quality of education being received by students at our universities. If we hope to produce first-class engineers, we must have first-class faculty, first-class graduate research programs, and modern, updated facilities. I strongly believe we need a combined government-academe-industry effort to address this problem.

Our engineering schools are struggling to attract and retain qualified faculty. Because bachelor degree holders in engineering can usually command much higher salaries by working in private industry than they can by pursuing advanced degrees and careers in teaching, an estimated 1,600 engineering faculty positions are currently unfilled.

With faculty resources stretched thin, and with many students showing a reluctance to pursue advanced degrees, our graduate programs and the fundamental research efforts in academe are suffering. This compounds the problem by making graduate level education less attractive to those students who might be inclined to seek it. Furthermore, our future engineering professors are not receiving the best possible education, and future generations of engineering students will suffer as a result. Additionally, industry needs for Ph.D. degree engineers are increasingly difficult to meet.

Finally, our universities are operating with aging, often outdated equipment. The increasing complexity of engineering technology and its associated equipment and instrumentation is causing the equipment and facilities in our universities to become obsolete at an accelerating rate. As an example, it is not uncommon to find electrical engineering schools whose laboratory facilities are dominated by electro/mechanical devices, despite the fact that solid state gear represents the current state-of-the-art.

We are all aware that tight university budgets are a fact of life that will be with us for the foreseeable future. In this budget crunch, expenditures for laboratory equipment tends to rank low on the totem pole. It is difficult to comprehend how we can maintain a leadership role in cutting-edge technology if our future engineers and scientists are being trained utilizing outmoded facilities.

As a society, we must make certain that our universities have the resources to carry out their role to train innovative and creative engineers and scientists and to carry out the leading edge fundamental research in the variety of sciences important to mankind. Those resources include both faculty and physical assets.

I do not suggest that this challenge is just the government's problem. While the federal and state governments have important roles to play in supporting our national R&D effort through higher education, the private sector also has a major responsibility. After all, business is the primary consumer of technical manpower. The National Society of Professional Engineers strongly believes that the solution to this problem requires a joint public/private effort.

We all know that Congress faces serious dilemmas in attempting to allocate scarce resources among pressing national needs. An effective government/industry program will allow us to expand and improve our university programs significantly without placing all the burden on the federal treasury. Furthermore, a cooperative effort will allow both the public and private sectors to maximize the impacts of their investments.

Therefore, I would urge this Subcommittee to give serious consideration to a matching grants program between industry and government. If such an initiative is properly structured to make industry, government, and the academic community equal partners, I believe we will be able to best allocate scarce dollars to meet this country's technology and technical manpower needs.

I would like to make two points concerning this proposal.

First, it should be flexible. The scope of projects eligible for funding should be wide, so that government officials, university faculty, and industry representatives can work together effectively to determine where support is needed. In this regard, grants should cover a broad range of research and technical education at our universities.

In particular, industry should have the opportunity to initiate grant proposals in cooperation with the university community. Business leaders have a first-hand knowledge of where the problems exist, and they will be able to provide valuable ideas for making a matching grant program work.

Indeed, private industry is already active in this area. To provide you with just one example, Monsanto Company is part of an organization called the Council for Chemical Research, which was started three years ago and now includes over 30 companies and over 120 universities. It has been organized to bring together companies which employ chemists and chemical engineers, and to increase industry support for and interaction with higher education. Our efforts are aimed at improving graduate level programs in chemistry and chemical engineering. This is our first year of full operation, and our companies already have pledged $3.5 million per year of added support for a three-year period. In other words, these funds are in addition to our past levels of support. In the case of Monsanto, you might be interested in knowing that we currently are contributing more than $10 million per year in support of education at the university level through fellowships, grants, scholarships, research contracts, etc. For U.S. industry as a whole current levels of industrial support for engineering and science education are probably in excess of $300 million per year.

In addition to direct financial support, hundreds of companies across the country are pursuing a variety of initiatives to aid colleges and universities in scientific and engineering education. These activities include student cooperative programs, adjunct professor assignments where industrial representatives spend part time on college campuses (frequently at company expense), equipment donations, summer employment programs for both students and professors, and programs to match gifts made by employees.

It is true that such efforts can and will continue without government involvement. However, I believe a partnership between government and industry would allow us to vastly increase the resources available to our universities via providing added incentive for academe to take initiatives on their needs and providing an opportunity for the marketplace to have an input on the distribution of the funds.

Mr. Chairman, I am aware that you discussed the possibility of a matching grants program with Dr. John Slaughter, Director of NSF, at the Subcommittee's March 25 hearing, and that the Subcommitee has expressed an interest in exploring that option. I would like to add my support to that idea and encourage thoughtful consideration of it.

I don't come here today with a specific dollar figure to propose for such a program. In an issue as complex as this, the viewpoints and perceptions are many. Some estimates on the cost to correct faculty shortages, enlarge graduate programs and upgrade facilities have ranged as high as $1.5 billion.

My own view is that a "quick fix" is neither practical nor possible and that the resources to be applied to the problem must come from a wide variety of directions including industry, individuals, foundations, state and local governments, and university fees and tuitions. In other words, it's a societal problem needing societal solutions. I further believe that relatively modest funds with maximum flexibility in their application to the most pressing needs—which are not common across the spectrum of public and private universities and colleges—could have a measurable impact on insuring our country's leadership in science and technology for the decades ahead.

In closing, I want to convey to you the National Society of Professional Engineer's strong support for a flexible matching grants program, and to offer you whatever assistance NSPE's membership and staff can provide in formulating such a proposal. As an organization representing professional engineers in industry, private practice, government, and academe, NSPE will be happy to provide you and your staff with information and recommendations as you may so desire.

Mr. Chairman, I appreciate the interest of you and your Subcommittee in this important issue. This concludes my prepared remarks and I will be glad to answer any question.

Senator SCHMITT. Thank you, Mr. Reese. You state that Monsanto is contributing more than $10 million a year to universities. Do you have any formula basis for doing that? As I recall, the Exxon Corp. ties the $15 million that they have committed—which, by the way, sounds small compared to what Monsanto may be doing—on a per asset or per sales basis.

Mr. **Reese**. I would suggest that $15 million, again, does not represent Exxon's total.

Senator **Schmitt**. I am sure it does not. But that particular effort is tied, I believe, Dr. David said, to the number of new employees that they hire from the university system. I do not remember exactly how they tied it, but I believe that is what he said. Do you have any comparable way of judging what your contribution should be?

Mr. **Reese**. No, we have not put the thing on a formula basis, but rather have addressed ourselves to those institutions that are of most significance to us, both from recruiting and also from the standpoint of where they are active. Obviously, with the interest we have in something like silicon, we are looking at organizations such as Stanford and others that are highly involved in advanced electronics. We have had longtime relationships with certain State universities who have premier chemical engineering departments. So we have done it more on that basis than trying to come up with a formula.

Senator **Schmitt**. A year or so ago in testimony before this committee, I believe it was the president of the American Chemical Society—I cannot recall which company he was with——

Mr. **Reese**. I believe Goodrich. It should have been, if it was a couple of years ago.

Senator **Schmitt**. Anyway, he indicated that the subject of investment in education had not to his knowledge been a subject of discussion at stockholders meetings, but that, in response to my question, it soon would be. Is this the subject of any interest to stockholders in Monsanto?

Mr. **Reese**. I would say to date it has never been an issue at our stockholders meeting per se. Occasionally there will be a question addressed to the matter of corporate funds being used to support various activities. But because of the science orientation of the company, we felt—I have always felt quite comfortable that there was justification for what we were doing in terms of the need for both the science that is being produced by the research program as well as the graduates. And so we have had no problem and publicly have said that is our position.

Senator **Schmitt**. So you do not feel that the investor resources committed to Monsanto are in any danger because of an inadequate level of contributions to research and education?

Mr. **Reese**. Did you say because of an inadequate level?

Senator **Schmitt**. Yes; do you think you are in a position to justify to your stockholders that Monsanto is contributing adequately to this problem, and necessarily?

Mr. **Reese**. What we are——

Senator **Schmitt**. I am not trying to put you on the spot.

Mr. **Reese**. I understand, but obviously our level of contribution is a balance between what we wish we could do in terms of acquiring and assisting additional basic research and basically how much money we have got available.

Senator **Schmitt**. But you do not know of any stockholders, based purely on the judgment of protection of their investment, who feel that you are not doing enough?

Mr. **Reese**. No. That is the other side of the coin. Nobody has come to our annual meeting and stood up and suggested that we should double, triple, or quintuple our level of support.

Senator **Schmitt**. But do you not think that to some degree all major basic industries are threatened in some way in the long term as a result of the deficiencies in specific areas, if not generally in engineering and science?

Mr. **Reese**. I think that is why you see now these initiatives on the part of industry to get together in groups and sensitize people to the issue. Frankly, there are some segments of industry that are not contributing even at the level that some of the rest of us are, and the objective of this Council for Chemical Research was within the chemical industry, that usually has had a pretty high understanding of the need for support of university research, to get some of those people up to the industry average kind of thing.

Senator **Schmitt**. So equity of contribution is of some concern within the industries themselves?

Mr. **Reese**. Well, it is just that each of us knows that we cannot do it by ourselves.

Senator **Schmitt**. But you also do not want any freeloaders, right?

Mr. **Reese**. I guess I am not so concerned over that, because somehow I figure that if we are highly involved with the university system we will have first place in line in terms of leading edge technology and we will run away from the other people if it is there.

Senator **Schmitt**. I understand that the CCR to which you referred has had to modify its original goal of $10 million per year for basic research at universities because of concerns by both the universities and industry. What concerns were they? Can you enlighten us?

Mr. **Reese**. To the best of my knowledge, the only concern thus far is that they had inadequate funds. Now, there was a lot of discussion initially as to the extent to which funds would be funneled through the CCR and how much they would be controlled by the company. For instance, the Exxon grant that you are talking about, the $15 or $16 million going to engineering schools, a large part of that would qualify as being the kinds of things that are being done by CCR. But Exxon prefers to administer this through Exxon rather than through the CCR. For our own funds, we have only allocated a half million dollars to the CCR effort, but we are administering the rest of it ourselves.

And so they have modified the original objective of the organization. Hopefully, they were going to try to encourage people to funnel all their funds through CCR, and I think, very clearly, quickly industry said, now wait a minute, we want to control where it goes, because we have to build the linkage between our basic businesses we are in and the university that it is going to.

Senator **Schmitt**. And so the majority of the funds, new funds, are still being allocated by the industry, by the companies themselves?

Mr. Reese. Yes.

Senator Schmitt. Is there some lingering university concern that these funds may come with strings that they do not want to accept?

Mr. Reese. I am not aware of any.

Senator Schmitt. Because you recall that in the fifties and early sixties the majority of research funds were in fact coming from nonpublic funds, or non-State funds, were coming from industry in almost all sciences, particularly chemical, geological, biological sciences. And then that started to become dirty somehow, and the faculties of various universities began to move away from the use of industrial funds in favor of Federal funds.

Do you see that that period of time may have passed and that now a balance is being sought between various funding sources?

Mr. Reese. Well, I think clearly, as Government funding has begun to dry up, we have become much more attractive to some of the university groups than perhaps previously. I think from an industrial standpoint, of course obviously many of our funds are aimed toward very specific areas of interest to the corporation, where in the Government grants many of those are on a much broader basis and perhaps more attractive.

On the other hand, the thing that I am seeing in my relationship with the engineering colleges is they are suggesting that the industrial funds come with fewer strings in terms of the administration and oversight. In the end they are better off with industrial funds than they were with the Government.

Senator Schmitt. I think that has become a realization in many circles.

Mr. Lindsay, your testimony referred to the 1980 CED report which pointed out the importance of basic research on education of scientists and engineers and the contended need for "the country at large to pay some portion of the cost in developing that talent through the financing of basic research work at the universities."

Does that report also acknowledge the responsibility for direct investment in university research and education by industry?

Mr. Lindsay. Yes, it does. Generally the point—the distinction or separation is that basic research, which has a long leadtime and which it is very hard for, in many, many cases, for individual companies either to see their industrial interest or to know how their support, even in the long term, whether it will feed back to support their shareholders—that that should come largely from the Government; that applied research and development should come primarily from industry.

And in the model I outlined to you, that is in fact what is going on.

Senator Schmitt. Back in the 1950's, I think it is safe to say that the majority of graduate student education and research related to geological sciences that was not being paid for by the students themselves was supported by the mining industry. That changed subsequently.

What proportion—well, I am not sure it is possible to say, but I will ask the question anyway. What proportion of graduate student and basic research in the university is being supported by industry today, do you have any idea?

Mr. LINDSAY. I do not have the figures on that, I am sorry.

Senator SCHMITT. Mr. Reese?

Mr. REESE. I think it is somewhere around 4 or 5 percent. If you take the R. & D. funds at the university level in science and education—excuse me, science and engineering, it is quite a small percentage, and of course that is a worrisome thing in terms of how do you build on that base.

Senator SCHMITT. Does the CED plan any follow-through action to implement the proposals for action, as reported at the National Engineering Action Council?

Mr. LINDSAY. CED is only one of several organizations that have participated in that conference. We do have under way two basic policy studies of our own which lead inevitably back to the issues that we are talking about here today.

One is on improving productivity within the United States and the other is a basic study on industrial policy, trade and international competition, both of which really come back to the productivity of our industrial society and in turn its base in science and technology. So that CED is continuing to build on—to build a coherent economic program and policy, whether it be on the technical side—employment, the hard to employ, capital investment, inflation, all of these things we are trying to weave together into a coherent strategy that has much more reliance on the private sector.

Senator SCHMITT. Did you have many disagreements? Was consensus really easy to obtain in these areas? And is that consensus being borne out as the proposals are more readily available to a broader base of industrial representatives?

Mr. LINDSAY. I think so. It might be interesting—it is not directly on the point, but indirectly—that in both groups in CED there is now a recognition that the problems—that in terms of productivity it is not essentially the blue-collar workers, but major improvements in productivity and the responsibility for them have to lie with management.

And with CED as a corporate organization, largely corporate, I am pleased to see us taking a look at our own house.

Senator SCHMITT. Of course it does take the proper allocation of resources to have the capital available to invest in new productivity, and I am happy to see that there is some movement in that direction on the part of management and labor in the new contracts for heavy industries. I think that is an extremely positive trend, although the so-called concessions are not as large——

Mr. LINDSAY. I agree, this is a very constructive trend and may have as fundamental an impact on slowing inflation in a continuing way, not just a blip, as anything that is going on.

Senator SCHMITT. It is a lot more positive than anything we have done up here. So keep at it.

Of course, that might have been expected.

Mr. Lindsay, Mr. Reese has indicated that if some kind of matching Federal-industry program were developed, that it ought to be as broad and flexible as possible. Do you agree with that or do you think we ought to target?

Mr. LINDSAY. I think it ought to be broad. In principle, I am all for it. I think there are some difficulties—there may be some difficulties, that perhaps for the long-term interest there may be some areas that ought to be funded now that are not as obvious to industry or to the public at large, and therefore on a matching basis if it is not administered in a way to level this out may end up in unduly investing in whatever is glamorous at the time or whatever industry may need in the shorter term, and neglecting the longer term.

And here I think Government has a role, the National Science Foundation, if it is properly managed, to take a good long look ahead and be sure there are no gaps that are going to be very important in the future.

Senator Schmitt. Can you give us an example or two?

Mr. Lindsay. Well, I would have said genetic engineering 10 years ago, but that is no longer—that clearly is now one of the glamor——

Senator Schmitt. You could say geological sciences and get some favorable responses from the chairman.

No, seriously, do you have any thoughts of where, either by discipline or in types of facilities or instrumentation, where you think targeting is appropriate? You see we would come back to the same people for advice on targeting or guidelines who would be making decisions that you think might be too short term.

So how do we sort this out?

Mr. Lindsay. Well——

Senator Schmitt. Do we let John Slaughter, as capable as he is, be the dictator of the set-asides?

Mr. Lindsay. I suspect he does not act as a dictator, but tries to bring in panels.

Senator Schmitt. But then he will be seeking advice from the same people that might otherwise have a short-term view. Now, that is not fair, because I have sat on panels of that kind myself and there is a synergism in a panel that tends to subordinate short-term interests often to longer term national perspectives. Why that happens I do not know, but that is one of the advantages of these panels.

Mr. Lindsay. And I think one of the advantages of academic participation as well. That in many ways has a longer viewpoint.

Senator Schmitt. You are saying that the compromise of opinions that results in these panels when they must make recommendations between academia, the industry and the Federal Government, tends to take a somewhat longer term view than that in which the industry itself might be interested?

Mr. Lindsay. I think that is true, but I also would not rule out the judgments, individual judgments of very creative people who are thinking ahead and not water down those judgments by trying to get a consensus and put some bets on some things that are out in the future that nobody knows whether they are going to pay off or not.

Mr. Reese. Mr. Chairman, let us put the thing in perspective a little bit. I have suggested that I think industrial support for R. & D. at the university level is something in excess of $300 million, and I think that the total bill is somewhere around $6 billion. I think pragmatically one would have to assume if you put a matching gift program in place you are not going to double the industrial level of support.

If we could end up by increasing it by 10 percent—and again I am assuming you would be looking for new initiatives; you are not looking for industry to attempt to take their same old, already established commitment and match it up against some funds from the National Science Foundation.

I would be far more concerned about how we draw up the guidelines to insure that this is new effort on top of the present situation. And then it seems to me it brings it down to the case, you know, looking at our CCR experience, that if we could increase the level of support by 10 percent in a given year that is pretty good. We are only talking about $30 million.

So I guess I do not share Mr. Lindsay's concern that we are going to distort the whole direction of university support. I would see this probably more clearly going into certain areas of faculty problems and equipment problems and things of that nature, in other words solving the crises and the fires, as opposed to necessarily putting in place longer-range basic research programs.

Senator SCHMITT. But you yourself advocated flexibility.

Mr. REESE. That is right.

Senator SCHMITT. And let the marketplace, so to speak, determine where the emphasis is. And I think all Mr. Lindsay was saying is that there might be one or two places where the marketplace would make a good short-term decision, but not a very good long-term decision.

Ten years ago, as he indicated, it would have been biogenetics. I doubt if there would have been much emphasis.

Mr. REESE. But I am also suggesting that probably pragmatically the size of that thrust is not going to be so great as to change the whole direction.

Mr. LINDSAY. I think that is probably right, but you want at the beginning of the cutting edge of a technology a few very bright, creative people at work and not a huge operation.

Senator SCHMITT. Well, do you have any instant advice for us on how we avoid just providing a match for what industry is already doing? And now that they have heard we are thinking about it, how do we keep them from reducing that contribution in anticipation that we may provide a match?

Mr. REESE. Well, you know, life goes on from a competitive situation, and the things that we are doing we think are right competitively. And it is hard for me to envision right at the moment anything that I would rush back and turn off by reason of the fact that hopefully you might do something. Pardon my saying so.

Senator SCHMITT. No; that is very perspicacious of you.

Mr. LINDSAY. I think most of the companies in high technology would respond the same way.

Senator SCHMITT. But practically, you would probably want to pick a time, say the first of this year, to start the clock and say it applies to new contributions matched, it applies to new contributions past that particular point in time. There are ways to do that.

Mr. REESE. Again, I would think that perhaps you could look for new kinds of activity that a corporation had not indulged in before. Let's say if we had not been in the habit of supporting equipment purchases—as a matter of fact we have been, but if we had not—let us say we as an organization moving in and doing that, that might qualify for a matched grant for company A, where it would not for company B.

Senator SCHMITT. There is another way. For example, we are currently at a certain number of fellowships and scholarships being supported by the Government. You might raise your target to a higher number, and where the match is applied across the board you just make it so that you are trying to get an increased number of scholarships at the same level of funding.

There are ways to do that, and we would appreciate any thoughts you or your organizations might have on specifics. Is there anything you would leave out, that you say absolutely we should not even consider a match? Instrumentation, fellowships, scholarships, university research, facilities upgrade? What about science teaching?

Mr. REESE. Are you talking now the university level?

Senator SCHMITT. No, elementary, secondary. Do you think industry would ever support a match in that area?

Mr. REESE. I guess I squirmed a bit this morning as I listened to the National Science Teachers Association, because I think as industry we are very concerned over this matter, the precollege education. And again, our problem is, how do you reach the thousands of local school systems across the country?

I can say for Monsanto, every place where we have a location I think you will find our people involved with the local school systems, attempting to be helpful. But again, we have 55 plants across this country, and the GE's and the IBM's and the Exxon's and all this, the same sort of thing. But we do not have the representation, and it is difficult for me to see how from an industrial standpoint we can tackle that precollege thing on a very broad base. And somehow this surely needs Government glue to hold it together and to set the pattern.

Senator SCHMITT. Well, what about a match to a company that at a specific facility would set up a program of summer or even continuing workshops for science teachers, that would give them added experience and background and knowledge, specific knowledge about the modern world of science and engineering?

Would a Monsanto facility—I lived near one in Clear Lake City for some time and knew the manager of that facility very well—of that kind ever consider setting up an actual workshop-type environment in which the local science and mathematics teachers could broaden their base of understanding and receive a grant for so doing?

Mr. REESE. As a matter of fact, we have done things of that nature. I am not sure whether we would step up our effort by 25 percent if there was some kind of a Government grant, because frankly the cost of doing this is more in terms of the time of the people than it is in any actual outlay of moneys that you make.

On the other hand, as I look at the equipment problem in many of the local school systems—math courses in need of computers and science classes with a need for better facilities—I bog down in terms of how do you reach that thing on a national level, and I just have reservations in my own mind whether a matching program would stimulate industry to do much more than they are doing.

It might be additional funds at the local level would be helpful, but I am just suggesting it might not stimulate us to do more.

Senator Schmitt. Of course, your employees have kids in that school system, so there might be a political interest in it within the corporate structure.

Mr. Reese. Right. That is, as I say, why we are active. We have to have good school systems where we have our locations.

Mr. Lindsay. One of the problems I think is some types of instrumentation—first of all, companies like to, wherever they can, get their own equipment—and this is particularly true in the small computer field, where they see a payoff in the future. But some types of equipment that is very important are made by small companies who do not have the resources to give this equipment on a very broad scale. It probably would make no effect, and the universities might be equal to their total sales.

Senator Schmitt. Well, as a final area for discussion, let's talk about specific dollars. Let us say that a broadly designed, flexible, coherent matching funds program was established and that everybody agreed with it. Do you think it would be possible to leverage about $20 million, which is the difference between the current NSF awards or the projected one for 1983, and those awarded in 1981—that does not sound like too big a number, but is that impossible? That would just bring us up to the 1981 levels.

Mr. Lindsay. My reaction is, with all the caveats that you have given, if it is regarded as a sensible constructive program, it seems to me $20 million in terms of the combined resources of the industrial community is well within the possibility.

Senator Schmitt. And also probably totally inadequate to solve our problems.

Mr. Lindsay. Yes; that is right.

Senator Schmitt. For instrumentation, just for your perspective, a $70 million program was proposed in 1982 and then withdrawn; $75 million, excuse me. The program was proposed and withdrawn. I presume your statement would apply there.

What do you think would be an appropriate match ratio? Should it be 50 to 50, 1 to 1, or 10 to 1 industry to Government or what?

Mr. Lindsay. I have not thought about that. If I had to grab a number, I would say 2 to 1, 2 Government to 1 private, would probably be the more effective than a 1 to 1 in bringing out a total amount.

Senator Schmitt. You do not have to commit yourself, but if you would allow us to contact you after you have thought about it a little bit, we will do that.

Mr. Reese. I think again it is a concern I expressed earlier as to how quickly and to what extent we can really induce industry to do more than they are doing already. And I think that if—you know, to get $20 to $30 million additional out of industry within the next year or two I think is going to be very difficult, despite the fact I think basically there is widespread concern over this problem.

But again, part of what you have to recognize is that we will continue to choose funneling some of our moneys in other directions, probably outside of the grant situation.

Senator **Schmitt**. Is there not automatically going to be some targeting by the industries that are presently in the growth stage and have the greatest need for scientists and engineers?

Mr. **Reese**. Absolutely, yes.

Senator **Schmitt**. So in the microcircuitry area right now——

Mr. **Reese**. Bioengineering area.

Senator **Schmitt** [continuing]. One would suspect there might be a greater potential for leverage than there would be in steel?

Mr. **Reese**. Right. But let us also recognize that when you add up all the total numbers and we look at that total $6 billion number, that is pretty big.

Senator **Schmitt**. It sure is.

Gentlemen, I want to thank you for your testimony today.

Thank you very much. The hearing is recessed.

[Whereupon, at 12:04 p.m., the hearing was adjourned.]

ADDITIONAL ARTICLES, LETTERS, AND STATEMENTS

STATEMENT OF HON. CHARLES A. BOWSHER, COMPTROLLER GENERAL OF THE UNITED STATES

Mr. Chairman and Members of the Subcommittee, this statement describes the status of our work on the research instrumentation needs of U.S. universities. We are conducting this work in response to a letter from Chairman Schmitt (dated July 29, 1981) in which he requested GAO to do a study that:

Analyzes studies and other relevant data to determine the causes and factors which influence the need for research equipment by universities; and

Identifies and evaluates options available for equipping university laboratories, including Federal programs, alternative financing plans, and depreciation schedules and tax incentives.

In this statement we will discuss our work to date on the first half of this request.

BACKGROUND—UNIVERSITIES AND INSTRUMENTATION

Under the present organization of the U.S. research and development effort, universities conduct the major share of basic research. In 1981, the universities and their associated research centers spent about $5.2 billion on basic research, which was about 59 percent of the Nation's total basic research expenditure.

For about 20 years, U.S. scientists have claimed, in studies and congressional testimony, that instrumentation available to academic researchers was inadequate, due primarily to insufficient funding. In recent testimony, various leaders of the scientific community have estimated the cost of updating university research equipment to lie between $1 billion and $4 billion. A more precise total does not exist. The variation reflects the lack of consensus on what a well-equipped scientist ought to have and on the number of scientists that should be well equipped.

SCOPE AND METHODOLOGY OF THE GAO STUDY

Our ongoing work does not attempt to determine how many university scientists lack adequate equipment. Nor do we attempt to determine how many scientists should be equipped or how sophisticated that equipment ought to be. Finally, we are not analyzing the impact of equipment shortages on research output.

Our objective is to analyze why this perceived shortage of research equipment exists. We draw on three sources of information:

(1) Expenditure data drawn primarily from various publications of the National Science Foundation (NSF).

(2) Major existing studies of the need for university research equipment. With few exceptions, these studies are concerned with demonstrating that an accumulated research equipment need exists, rather than assessing the causes of this perceived shortage. An annotated list of the major studies is attached to this statement.

(3) The result of interviews with over 200 researchers and administrators during site visits to 8 universities, 4 private research or business organizations, and 4 Federal agencies. The universities were selected on the basis of a combination of characteristics: research eminence, amount of research expenditures, geographic location, and the level of financial support from non-Federal sources.

For the analysis that follows, we define research equipment as instrumentation used in scientific experiments which can be installed in a given laboratory without large physical plant modifications or new construction. While this definition is a useful start, data problems remain. No trend data exist on nationwide research equipment expenditures by universities. (NSF is studying how such data could be collected.) Similarly there do not exist comprehensive indexes which would measure changes in the price of equipment or the costs to maintain it. We rely on our interviews and a few small studies for this information.

INFLUENCES ON UNIVERSITIES AFFECTING EQUIPMENT ACQUISITION

Existing studies of research equipment needs identify the following principal causes for the perceived shortage: Constant funding for basic research, increased acquisition and maintenance cost for instrumentation, and inflexibility in the granting process.

Based on our own analysis and interviews, we add to this list: financial disincentives contained in Office of Management and Budget (OMB) Circular A-21, and the apparently common practice of funding research staff in lieu of replacing aging research equipment.

Funding for instrumentation

Except for some yearly fluctuation, between 1968 and 1977, constant dollar (1972) expenditures for basic research at colleges and universities were essentially constant.* An upswing began in 1977 but expenditures declined from 1980 to 1981. Overall expenditures increased 10 percent in constant dollars from 1968 to 1981, with the major increase occurring since 1976. Figure 1 shows this overall trend, as well as the share of expenditures by the Federal Government

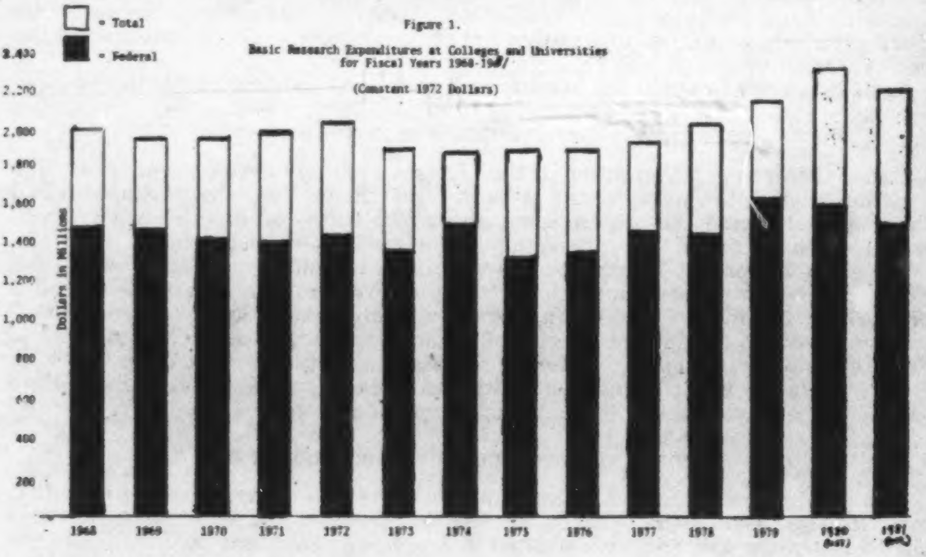


Figure 1.

Basic Research Expenditures at Colleges and Universities for Fiscal Years 1968-1981/

(Constant 1972 Dollars)

Increasing cost of instrumentation

In light of essentially constant funding, as indicated above, major price increases have had a large effect on researchers' acquisition and maintenance of research equipment.

All available data, although limited in amount, support the contention that the price of advanced research equipment had increased faster than the general inflation rate. Most of these calculations are on the basis of increasing costs to do a particular kind of research, rather than on the increasing cost of a particular piece of equipment. However, in a study of the IBM Research Division, it was calculated that a "market basket" of about 126 items of research equipment increased in cost at a 16.4 percent annual rate between 1975 and 1981.[1] A 1980 Association of American Universities (AAU) study [2] cites figures of over 20 percent for annual cost increases from several data sources for research equipment used in chemistry.

Maintenance costs also have been cited as increasing rapidly. The 1980 AAU report presents a staggering example of costs which doubled for a particular facility over a 4-year period. A 1971 National Academy of Sciences (NAS) study [3] estimated average maintenance costs at 10 percent of the original cost of an instrument per year. Science magazine noted that equipment maintenance service charges have reached $100 per hour in some instances, which includes travel time for the technician. Our interviewees generally confirmed the occurrence of maintenance cost increases. However, we have been unable to locate any aggregate data on maintenance need and costs.

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*All data in this section come from various NSF publications.

[1] Draft Report of the Ad Hoc Working Group on Scientific Instrumentation, National Research Council, Apr. 2, 1982, p. 35.

[2] The Scientific Instrumentation Needs of Research Universities, 1980.

Inflexibility in the granting process

The present research grant funding process makes it very difficult for several researchers to jointly purchase expensive instrumentation to be shared during their research projects. This is especially true when the grants come from more than one agency. This point was made by many researchers with whom we spoke. NSF is conducting a promising experiment in its research grant administration which, among other characteristics, would facilitate multiproject purchases of research equipment. Early indications are that researchers are making some use of this new concept to more easily purchase expensive equipment. However, this experiment is just a beginning. It does not address the difficulty associated with groups of researchers attempting to acquire instrumentation from several agencies during the proposal stage of the research funding process.

OMB circular A-21

Under the formula in Circular A-21 for calculating rates for cost recovery for federally funded research, there are two provisions which may be causing problems for universities. First, the portion of a university's equipment purchased with non-Federal funds is considered to be used at a rate of 6⅔ percent per year which is equivalent to a useful life of 15 years. This provision ostensibly exists to enable the university to recoup funds for the renewal of equipment as it wears out. However, the 15-year recoupment may not be consonant with scientific advancement and its requirement for new equipment design. The NAS 1971 report estimated that the useful life of laboratory equipment may be closer to 5 years, while researchers we have interviewed claim that for some quickly advancing fields it is sometimes less than that. Second, Circular A-21 does not allow a university to be reimbursed for interest expenses. We were told that this adds to university's difficulty in raising funds to acquire equipment which is not purchased with Federal funds. It recent OMB-proposed changes in Circular A-21 are adopted, interest charges for equipment costing over $25 thousand will be allowed.

Trading equipment for research staff salaries

Principal investigators have been forced to make choices to keep research proposal costs within overall budget constraints. We were told repeatedly by senior researchers and university administrators that when times are tight, the first proposed expenditure to be cut is for new equipment. The investigators appear to do their best in keeping money to pay their research team—the associated faculty, post doctoral researchers, and graduate students. It may take many years to develop a strong team of researchers to do a particular kind of research. When the choice is between letting go a research associate and buying equipment, it appears that a research team can always "make do" with a particular piece of aging equipment for another year.

Unfortunately, there is no documented evidence of the magnitude of these trade offs of equipment purchase for people support. This appears, however, to be a common occurrence in every university laboratory we visited.

Perhaps researchers make these trade offs in the belief that they have no alternative. Perhaps the practice is increased due to the difficulty in determining with any precision when a particular piece of equipment is obsolete and needs to be replaced.

We can distinguish between two kinds of obsolescence—physical and scientific. Physical obsolescence refers to an item that breaks down and is no longer seen worthy of repair. This does not occur at any precise time—it seems that equipment can frequently be repaired. Determining whether to repair a piece of equipment may depend on many factors such as the time and ease of repair, cost of repair, availability of parts, and cost of replacing a piece of equipment. An appropriate analogy may be with an automobile owner with an aging car. At what point will it no longer be worthwhile to repair a car and, instead, purchase a replacement?

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[3] An Assessment of the Needs for Equipment, Instrumentation, and Facilities for University Research in Science and Engineering, 1971.

Scientific obsolescence is even more difficult to define. It can occur long before breakdown (physical obsolescence) or even before the instrument is no longer capable of generating data that contributes to published results. The ambitious researcher wishes to advance his/her research at a rapid pace. If a piece of equipment does not enhance that research effort by providing appropriate technological assistance, it is seen as scientifically obsolete. However, that same instrument may have years of useful life remaining for research performed by other scientists with different research objectives.

We found no methods that can determine absolutely when scientific obsolescence has occurred. We were told repeatedly by researchers that, if they couldn't purchase or get access to a particular piece of equipment, they would attempt to alter their research objectives to compensate. However, such flexibility for individual researchers, combined with continued deferred investment, may not translate into the best use of our scientific capabilities.

Existing studies attempt to determine obsolescence of laboratory facilities by comparing the "best" university laboratories with similar laboratories in other nations and with facilities in industrial laboratories. The 1980 AAU report noted, and our interviews corroborated, that many scientists in the best university laboratories have seen research laboratories overseas that have far more modern research equipment for similar research. However, there are no studies that systematically document this by comparing the state of equipment available to basic researchers in various countries.

The 1980 AAU report on university research instrumentation needs presents limited data comparing the best university and industrial laboratories. AAU concluded from its small sample that the median age of equipment in industrial facilities was almost half that of the best university laboratories. Thus, they concluded that on the whole, the industrial facilities were far more advanced.

CONCLUSION

In this statement we have described several causes for the perceived need for research equipment. In every case, there is a tremendous lack of information. We believe more information is needed to assist policymakers in assessing whether the need is diminishing or growing; and developing standards on what constitutes a "normal level" of research equipment need.

ANNOTATED BIBLIOGRAPHY OF MAJOR STUDIES

The following 13 studies are particularly descriptive of the state of university instrumentation. They are listed alphabetically by title.

"An Assessment of the Needs for Equipment, Instrumentation, and Facilities for University Research in Science and Engineering." National Academy of Sciences, September 1971. This study evaluates the equipment needs of research universities as indicated by a sample of 8 science and engineering departments in each of 10 major disciplines. This was the first study to document the deteriorating research equipment situation across the major fields of science in the "post-Sputnik" era. It called for an ongoing effort to monitor and assess instrumentation needs in all major science and engineering disciplines.

"Chemistry: Opportunity and Needs." National Academy of Sciences, National Research Council, Washington, D.C., 1965. This study is one of several discipline-oriented studies sponsored by the National Academy of Sciences in the mid-1960s through the early 1970s. Instrumentation is one of many issues studied that are related to chemistry. The study looks at the history and uses of instrumentation for basic research, and examines the cost and financing of instruments. It provides documentation of a national deficiency in instruments in university chemistry departments.

"Equipment Needs and Utilization." Final Report to the National Science Foundation Advisory Council, 1978. This study was done by Task Group #5 of the National Science Foundation Advisory Council. The objective (task) of the group was "to discuss and document research equipment needs within the university environment, and the role of Federal funding in alleviating these needs. Included would be the replacement of obsolete equipment and acquisition of additional equipment and related facilities." This study contains a comprehensive set of findings and recommendations.

"Expenditures for Scientific Research Equipment at Ph. D. Granting Institutions, FY 1978." Irene L. Gomberg and Frank J. Atelsek. Higher Education Panel Report, Number 47, American Council on Education, March 1980. The American Council on

Education, through its Higher Education Panel, studied the university equipment situation for the National Science Foundation. The study collected information for the 1978 fiscal year on the level of institutional expenditures for research equipment, the Federal contribution to those expenditures, and the share of the funds spent on high-cost items. This is the only study that attempted to collect data on expenditure for equipment by all disciplines.

"Extramural Instrumentation Funding by the National Institutes of Health." Prepared by Dr. Kirt J. Veneer, April 1981. The purpose of this report was "to retrospectively view and comment upon the fact of equipment request made as part of regular research grants as they moved through the review process prior to funding." Three types of data were reviewed: evidence put forward to substantiate obsolescence claims; the funding of equipment by all Bureaus, Institutes, and Divisions in the National Institutes of Health (NIH); and the pattern of funding for two NIH institutes. This study provides a unique description of the extent to which a single Federal agency contributes to the funding of research instrumentation as a part of project-oriented research programs.

"The Life Sciences." Committee on Research in the Life Sciences and Public Policy, National Academy of Sciences, Washington, D.C., 1970. Like the previously mentioned study on chemistry, this was also one of several discipline-oriented studies sponsored by the National Academy of Sciences. Instrumentation is one of several dimensions of life sciences that are examined. Instrumentation is examined as a tool of biological research and as a requirement "for the future of the academic endeavor in the life sciences." Separate questionnaires were used to collect data from individual academic scientists and from department chairmen.

"The Nation's Deteriorating University Research Facilities." A Survey of Recent Expenditures and Projected Needs in Fifteen Universities. Prepared for the Committee on Science and Research of the Association of American Universities, Washington, D.C., 1981. This study is a companion to the 1980 AAU report on instrumentation needs (listed below). It was a preliminary investigation into some of the unanswered questions raised by earlier studies concerning facilities. Expenditures for the last three years and anticipated spending for four years were collected from 15 universities for new construction, facility modernization, major repair and renovation, and special research equipment. The sources of funds were not identified in the data.

"Research Equipment Assistance Program: A National Science Foundation Research Management Improvement Project Research Report." Volume I—Basic Report; Volume II—REAP Office Procedure Guide; Volume III—Computer Support User Manual; Volume IV—Implementing an Equipment Assistance Program. Iowa State University, October 1976. The objective of the study was "to describe a cost effective, rapid response system for assisting faculty researchers and teachers with scientific equipment and equipment-related needs through sharing, loans, and transfers. Faculty cooperation in sharing was achieved through a voluntary system independent of property accounting." This program forms a model for other universities to copy in their effort to meet Federal requirements for equipment sharing.

"The Scientific Instrumentation Needs of Research Universities." A Report to the National Science Foundation by the Association of American Universities, June 1980. The principal objectives of this study were "to assess the current status of scientific instrumentation in the major research universities and to identify factors which either facilitate or impede its development, acquisition, use and maintenance." Estimates were made "of the future consequences of current instrumentation funding policies on the capacity of the research universities to conduct productive research."

"Shared Use of Scientific Equipment at Colleges and Universities, Fall 1978." Frank J. Atelsek and Irene L. Gomberg. Higher Education Panel Report, Number 44, American Council on Education, November 1979. This survey "gathered information about the kinds of formal and informal procedures colleges and universities follow to facilitate sharing of scientific equipment . . . . The methods of sharing range from small-scale cooperative arrangements between departments to sophisticated institution-wide computer maintained systems." This is the only study to systematically collect data on the shared use of scientific equipment at colleges and universities.

"The Snowbird Report—A Discipline in Crisis." Computer Science Board (1980 Biennial Meeting). Communications of Associations for Computing Machinery, Volume 24, Number 6, 1981. This report was developed during the 1980 biennial meeting of Computer Science Department Chairmen. It is the result of intensive discussions about the crisis in computer science. Brief mention is made of the need for "computing facilities capable of sustaining experimental research." An appendix to this report shows the levels of capital investment per researcher required for different standards of research facilities.

"The State of Academic Science: The Universities in the Nation's Research Effort." Bruce L. R. Smith and Joseph J. Karlesky. New York, Change Magazine Press, 1977. This study examined the universities' role in the Nation's R&D effort. It discusses instrumentation needs as one of several emerging issues in academic research. It identified "the deterioration of instrumentation and other supporting resources for academic research" as one of four factors that was causing "uncertainty and anxiety" about the continued strength and vigor of the academic science enterprise in the United States.

"A Study To Improve the Management of Costly Instrument Centers." A Report to the National Science Foundation by the Department of Chemistry, University of Utah, 1975. In this study, the authors "examined the distrubtion of major instruments and the various forms of management practices involved in instrumental support of chemical research which have evolved in the U.S. and selected foreign countries." The authors also attempted "to assess operating costs of instrumental services under varying circumstances." Information on both the instrumentation situation in Europe and on the operations and needs of chemical instrumentation centers are unique contributions to the understanding of the situation.

STATEMENT OF DR. F. THOMAS JUSTER, DIRECTOR, INSTITUTE FOR SOCIAL RESEARCH, PROFESSOR OF ECONOMICS, UNIVERSITY OF MICHIGAN

Mr. Chairman and members of the subcommittee, my name is F. Thomas Juster, and I an Director of the Institute for Social Research and Professor of Economics at The University of Michigan. By way of general background, I am an Economist with an interest in the behavior of households and the measurement of well-being, and a Fellow of the American Statistical Association. At present I am a member of the Advisory Committee to the Congressional Budget Office, of the Consumer Advisory Council to the Federal Reserve Board, of the American Statistical Association's Advisory Committee to the Department of Energy, and am Chairman of the Executive Committee for the Conference on Research in Income and Wealth.

I am testifying on behalf of my own institution (the Institute for Social Research) and on behalf of the Consortium of Social Science Associations, which represents some 150,000 social scientists in the U.S.

SUMMARY

My statement relates to the research program of the National Science Foundation, and in particular to the Social, Economic and Behavioral Sciences part of the program. I would like to make four principal points.

First, investments in knowledge are fully as important for increasing our lagging productivity growth as investments in factory buildings, machines, or new technological applications.

Second, investments in knowledge about the functioning of society and the economy, which is what social scientists do, warrant fully as much priority and have fully as much payoff as investments in knowledge about engineering, physics, chemistry, biology, mathematics, geology, atmospheric sciences, etc.

Third, the present and recommended funding levels for the support of Social, Economic, and Behavioral science programs within the National Science Foundation represent a serious misallocation of scientific resources: While it is difficult to make judgments about how big the various scientific programs ought to be, the social sciences have been allocated substantially fewer resources than their quality or their potential contribution to society would warrant.

Fourth, a substantial number of important research activities that have already been proposed and approved cannot be undertaken within the fiscal year 1983 budget levels recommended for the Social, Economic, and Behavioral Sciences. Perhaps of even greater relevance, there is an extensive array of research topics of the highest priority that cannot even be contemplated within the recommended budget levels.

The utility of basic research

One of the most important and perceptive generalizations about human behavior is that "knowledge is power." Everyone on the Subcommittee has heard that before, and everyone probably agrees with it as a general statement. But it is important to understand that useful knowledge is a public good that cannot be produced without public support. It is not that brilliant ideas—genuinely new insights about physical or social phenomena—can automatically be generated by providing research funds to scholars, but that these insights do not become usable knowledge until they have been refined, elaborated, explored, and tested by people trained in scientific methods and enthusiastic about scientific inquiry.

How new ideas are generated is always something of a mystery. But how a fund of useful knowledge is produced is no mystery at all—it takes sustained investments in exploring the boundaries of the various scientific disciplines. Those investments feed on each other—the exploration of new ideas almost always raises more questions than it answers—and that iterative process is how scientific progress is made.

It is important to understand the nature of the payoffs to the new scientific knowledge generated by basic research programs. We know that the practical payoffs are long-delayed in time and are highly uncertain with respect to specific projects. Research in both the natural and the social sciences is not dissimilar to drilling for oil—a large number of explorations are expected to yield one or two big gushers, a couple of moderate-size producers, and a good many dry holes. The exploration program as a whole is worthwhile if the yield from the producing wells repays the investment in the dry holes, in addition to their own investment costs. Since no one can predict in advance which idea will become a big gusher and which will be a dry hole, it is necessary to take risks—with the strong presumption that some projects will not (with the benefit of hindsight) have been worth undertaking.

The analogy between basic research and drilling for oil is not quite perfect. The biggest discrepancy is that scientific "dry holes" usually lead to some useful scientific consequence—as a minimum, we can put to rest a theory that turns out to be fatally flawed.

Finally, we know from studies in areas where the practical returns can be identified that most research ideas produce socially useful products with a considerable time lag and often in unpredictable ways. And we also know from such studies that the overall rate of return to investment in basic research is very high:

A study of the return to private sector R&D estimated that the total societal rate of return is between 50 and 100 percent per year—a good deal higher than the return to private investment (generally 15-20 percent), and several times higher than the private rate of return to R&D (estimated at 25 percent). These results imply that the private sector will tend to underinvest in basic R&D if profitability is the sole guide, and suggest that the public sector is likely to underinvest in R&D relative to other forms of both public and private investments.

In a study of the relation between government investment in R&D and economic productivity, the principal impact on productivity was indirect and appeared only with a significant lag of more than three years. Interestingly enough, government-sponsored R&D influenced productivity mainly though its impact on private sector R&D, rather than directly.

A study in the biomedical sciences indicated that of a number of seminal ideas, more than half did not produce useful results until some 20 years after they had been discovered, and close to half had eventual application in areas that were unrelated to the original purpose of the study.

The utility of social science research

The landscape of social science concerns ranges from micro problems such as the way in which the human brain receives and processes external stimuli to macro problems such as the causes of conflicts between nations. Most social scientists worry about problems somewhere in between—they investigate the structure and stability of family relationships, or the dynamics of voting behavior, or the way in which schools and families participate in the process by which children learn, or the saving and spending behavior of consumers, etc. As a generalization with many exceptions, most social scientists are concerned with the attempts to achieve a richer understanding of how society and the economy actually work, with the ultimate objective of providing decision-makers with two types of insights—an accurate description of economic, social and political conditions in society, and a set of theories or generalizations which will enable the ultimate users of scientific findings to understand, and sometimes predict, societal change.

The returns to basic social science research have a significantly different character than the returns to research in the natural sciences. In particular, the private sector return may be substantially smaller, while the return to decision-making in the public sector is substantially greater.

In the private sector, the returns to social science research are in large part embodied in the training and skills of people that staff various business organizations—corporate strategic planning groups, financial planning groups, marketing groups—as well as firms that provide consulting services to corporate and non-corporate business. These skilled people then use social science concepts and tools—economic modeling, systems analysis, personnel testing, market research, program evaluation, operations research, etc.—to aid business decision-making.

There are occasionally more direct private sector uses—a recent illustration is an active interest on the part of pharmaceutical manufacturing firms to adapt the extensive research on quality of life to assess the contribution of pharmaceutical interventions to the health and well-being of the U.S. population.

But the principal returns to basic social science research are not directly on private sector performance; rather, they are in the provision of a basic framework of information and analytic insight that helps us to understand how our economy and society actually work. Besides providing the basic information and analytic framework for such understanding, social scientists also contribute a critical assessment of ideas about how to make the economy and society work better, they substitute facts and tested theory for myths and stereotypes, and they provide insights into the characteristics of important social and economic problems, such as inflation, productivity, crime, population change, etc.

The role of information and data

I believe that the Committee should pay special attention to the role of information and data in the social science research programs of the National Science Foundation. Supporting an adequate flow of relevant data about society and the economy yields a number of benefits:

(1) Viewed simply as descriptive statistics, information about society and the economy provides an essential background for an informed discussion about policy or the consequences of policy changes: A solid information base serves as a benchmark from which changes can be measured and analyzed.

(2) A carefully designed information base is an indispensable ingredient for the development and refinement of theoretical and conceptual structure.

(3) Well-designed scientific data bases, especially those with longitudinal characteristics, offer the best prospect for achieving a base of tested and reproducible social science knowledge.

Let me provide a few simple illustrations of the role of relevant and reliable information in setting a framework for policy discussion and formulation. As suggested above, an important function of social science research is to help inform such discussion.

It is widely believed that the U.S. voting public has become disenchanted with the political system and is therefore less inclined to vote.

It is widely thought that the U.S. labor force, particularly blue collar workers, have become increasingly unenthusiastic about the work environment, and are therefore increasingly inclined to loaf on the job.

Many people appear to believe that the U.S. welfare system has created a large underclass of families that are permanently dependent on welfare payments.

Our existing knowledge of behavior suggests that none of these perceptions is accurate:

Voter turnout is not lower than several decades ago, and there is no discernible relationship between variations in turnout and measures of voter cynicism or disenchantment.

There is no convincing evidence that worker dissatisfaction with the job is higher than in earlier decades, and a recent study of the "intrinsic rewards" from work suggests that people get more satisfaction from work than from most leisure activities.

The proportion of U.S. households that are permanently dependent on welfare (in the sense that they received more than half of their income from welfare payments every year for a decade) is less than one percent, compared to the roughly 10 percent of U.S. households who received welfare payments during a recent typical year.

An important characteristic of the data-base programs at the NSF is that they provide a reusable resource. A well-designed scientific data base will turn out to have hundreds of both academic and public-policy users over its lifetime. It will be the source of applied scientific work by academic and policy users who want to estimate response parameters for various types of behavior, a source of testing and refining theory, and a source of generating new and richer theory. Thus the returns from the creation and maintenance of these information bases extend for a long period of time into the future.

The Subcommittee should note several other characteristics of the NSF program targeted on development of scientific databases. First, these require substantial and sustained resources, relative to the typical analytical project which comes in smaller pieces and may not extend beyond two or three years. For example, one such database project at my own Institution costs roughly $1.5 million annually, and its useful duration extends for at least another decade. In constrast, the typical analytic project at NSF runs between $50,000 and $100,000 annually. Second, these database projects are the natural focal point for sustained interdisciplinary and team oriented research activities. Finally, these large continuing measurement oriented programs have a capacity to change the face of scientific understanding in a way that smaller scale and more isolated activity, however meritorious, do not. The Subcommittee will of course recognize that the scientific database projects are in many respects the social science courterparts of support for the national laboratory facilities in the natural sciences.

The budget recommendations

The social science part of the National Science Foundation has tended to run at approximately five percent of the total—in 1980, for example, the Social, Economic and Behavioral science programs had roughly $50 million out of approximately a one billion dollar total. Even with that comparatively modest amount of resources, NSF's social and behavioral science program looms large in qualitative terms and has an efficient multiplier effect. By adhering to the highest standards, by locating the best and most creative talent, and by emphasizing innovative and basic work, the program magnifies research capacities and our national resources through four principal functions:

(1) Support of basic theoretical work in the various disciplines;

(2) support of methodological/statistical work related to the collection and analysis of data;

(3) support of new initiatives, often risky ones, with the potential to extend the reach and power of the various disciplines;

(4) support of large-scale measurement projects, including the continuing collection of scientific data with the potential to monitor societal change over time and to provide the basis for the testing and refinement of theory.

The Administration's recommendation last year was to cut the $50 million dollar budget at NSF to approximately $20 million—a cut that would have destroyed the integrity of the program. As a consequence of the strong support for the Social, Economic and Behavioral Sciences shown in the Congress, the NSF restored some $11 million to these programs. This indication of Congressional support for social science research was received with great appreciation by the social science community, although we are also painfully aware of the fact that the current level of support is just about half, in real terms, what it was two years ago. Moreover, as one of my colleagues remarked in testimony before the House Subcommittee on Science, Research and Technology, we know that the glass is half empty rather than half full because we have just seen it being emptied.

The current budget recommendation essentially calls for continuation of the fiscal year 1982 level, although the NSF as a whole was recommended for an approximately seven percent increase over fiscal year 1982.

I do not think any defensible case can be made for the proposition that the social sciences have less utility to the society, or to the Congress and the Administration, than the natural science program within the NSF. They obviously produce a smaller total flow of useful products, since they receive a smaller amount of total resources. But the only study that seriously attempted to compare the quality of social and natural science research at the NSF came to the conclusion that, at the margin, the former was at least as high quality as the latter. Thus I urge this Subcommittee to restore funding of the social science programs at the NSF to reasonable levels—say, those prevailing in 1980.

The case for such restoration of the NSF budget seems to me quite strong, both on scientific grounds and on grounds of prospective payoff. Whether that is accomplished by reprogramming of resources allocated to the various research and other activities, or by augmentation of the NSF budget to allow restoration of the social science programs to 1980 levels, is an issue that can reasonably be argued either way. My own view is that basic research and development is more important than usual even in the current constrained economic environment, and that augmenting basic research resources should represent a high priority for the Congress. But budget constraints are evident, and the Congress may not be able to justify adding resources to scientific research when severe program cuts are proposed in most other areas.

I would point out that even with restoration to 1980 levels, the social science programs would still have suffered an erosion in real terms of some 20–25 percent, a degree of constraint that seems to me about the same as that being proposed elsewhere.

What would be accomplished by increased social science funding?

At the budget levels recommended by the Administration, a substantial set of research activities could not be supported. For example, a large set of programs concerned with the development of large-scale longitudinal data bases have already been approved by the scientific review process within the NSF, but the recommended budget provides resources for only three of them to operate at levels consistent with the collection of new data, and even then on a non-optimal scale. The other programs will be in a "hold" pattern, pending the availability of resources: that strategy may work for a year or so, but erosion (of staff, etc.) followed by abandonment is inevitable unless reasonable funding becomes available.

As illustrations, the budget will not accommodate the collection of annual data on the General Social Survey (which documents trends in a wide variety of social conditions in the U.S. population), or on the time use of American households (which permits current analyses of the underground economy, of volunteer activity, and of changes in labor productivity based on reliable estimates of time spent at work), or expansion of the environmental database, or collection of new data on the perceived quality of life among U.S. households. And even in such high priority- and event-bound data series as the Panel Study of Income Dynamics and the National Election Studies, only minimal rather than optimal data collection efforts can be sustained. In short, a set of programs with extremely high priorities from the point of view of understanding societal change and furthering the development of social science theory cannot be sustained within the recommended budget.

In the area of theory, methodology and new initiatives, the available resources require either rejection or sharp curtailment of a substantial amount of the highest quality proposed research. In my own institution, for example, a number of such proposals have been funded but at levels half or less those required to do the job effectively. Other proposals have been approved in principle as high priority, but rejected because of insufficent funding.

The impact on the Social Science programs of the present funding constraints varies considerably across the different programs. In some areas, program managers have opted to maintain quality, keep the same number of active projects, but cut project budgets—thus deferring decisions about which areas to eliminate. The hope is that the research activities would be reduced less than implied by the cuts in project budgets—presumably universities and their faculties will one way or another absorb the difference. That may or may not be the outcome in the short run—but it will certainly not be the outcome in the long run.

Other programs have adopted a different strategy. In sociology, for example, major programs in Statistical Methods involving log-linear analysis, network analysis and risk analysis have already been sharply curtailed and can be expected to decline further, and studies of the way in which organizational processes influence worker mobility, job satisfaction and productivity are threatened with discontinuance.

In the Measurements Methods and Data Resources program, a major program of research on survey methodology has been sharply curtailed, and a set of major initiatives designed to produce public use files from governmental data archives has been severely truncated. Given the amount of money spent in both the public and private sector on various types of surveys, research into improvements in survey design (increasing the validity and reliability of survey responses, and exploring alternative survey technologies) has a great deal of potential payoff. And providing both academic and public policy users with access to a public use file extracted from government data archives is a cost effective way of exploiting the research potential of data obtained originally for non-research purposes.

Not only is it true that highly valued research activities of a continuing nature cannot be undertaken within the recommended budget, but that budget largely precludes a number of important new initiatives. Let me cite a number of research areas where there exist promising new initiatives with major public policy as well as scientific importance: these are gleaned from my own experience and that of a number of my colleagues. It is obvious that many more illustrations exist.

Saving behavior

We are presently concerned as a society about the adequacy of personal saving to support appropriate levels of capital formation. It is recognized that an increase in the rate of capital formation is esential to the improvement of productivity performance, and that the required capital formation depends on an adequate flow of private savings. But the fact of the matter is that we have little tested and reliable knowledge about what determines private saving behavior, how saving might change in reponse to various tax or other stimuli, what will happen to saving as the population ages and as private pension coverage increases, etc.

One important reason for the uncertainty about our knowledge of saving behavior is the virtual total absence of an accurate set of data that measures personal saving, and its change over time, at the level of the individual household. The best such data were obtained almost two decades ago, while the most recent data (of dubious reliability) were obtained in the early 1970's. Neither of these studies has a longitudinal dimension.

It is possible to design a study that would fill this gap, but it would be very costly (perhaps $5–10 million) and would have to represent a long-term commitment over something like a five year period. Unless that gap in knowledge about behavior is filled, we will not know much more after the next decade than we know now, and the same unanswered questions will exist. But in the current environment, one could not justify the considerable effort needed even to prepare such a proposal, knowing full well that it cannot be afforded.

Productivity of the firm

Despite all the attention paid to the recent decline in national productivity, our ability to understand productivity change at the level of individual firms is severely hampered by the information base. It is not that we lack data on firms that relate to productivity; but we do not have longitudinal data at the right level of aggregation (the individual firm, where investment decisions are actually made), and the available data are not really well-suited for productivity analysis since they were not designed for that purpose.

Creation of a productivity-oriented data base for individual firms will yield substantial benefits only if it is seen as a long-term effort: Analyzing changes in the investment and productivity of the same firms over extended periods of time is generally agreed to be the only effective way to address the problem.

Family structure and development

Impressive evidence has accumulated during the last decade that family configuration (family size, birth order, spacing of children, etc.) has systematic effects on intellectual development. There are good reasons for believing that the model developed to explain these effects might also be useful in explaining other aspects of development as well—socio-emotional development, the development of loyalty and role specialization in families, etc. To pursue this potentially rich harvest of theoretically and pragmatically important outcomes would be expensive—there would have to be a longitudinal survey reflecting an adequate national sample of the various types of family configurations.

Technology and organizational structure

A great deal of production-oriented behavior takes place in group settings. This is true for military activity, workplace activity, and educational activity, to name just three. Moreover, the nature of much of this group-oriented interaction is likely to be substantially changed in the near future by the addition of a new interaction element: computers and robots, intellectual and mechanical resources never before under the direct control of work groups. We need a major program designed to answer questions like:

What modes of human resource organization and management are most likely to promote individual well-being and organizational productivity?

How can technological change be managed and organized to gain maximum productivity benefits while maintaining and promoting worker well-being and minimizing the social and economic dislocations often associated with new technology?

Are new forms of organization and worker-management relations needed to keep individuals, organizations, and our society viable in an increasingly competitive world market?

Given our failure to apply what past generations of social scientists have learned about group functioning and work behavior (relative to the applications of the Japanese) we probably require a major effort focused both on generating and applying the next round of relevant knowledge. And it would be a great advantage to program this activity so that it creates ready links between basic studies of group processes and applied studies of group behavior in relevant settings.

Health and human behavior

Health care currently consumes about 10 percent of our national product, and that figure has been rising rapidly. It is coming to be recognized that a major cause of adverse health outcomes is not the failure of medical technology but the perverseness of human behavior. Thus the next frontier in health research (and especially in medical care cost containment) is likely to lie in research that makes possible an understanding of the behavioral causes of many of our major trauma and serious illnesses: smoking, alcoholism, drug abuse, lack of exercise, poor diet, bad sleeping habits, and failure to use seat belts.

Both longitudinal and field-experimental research are needed to test the predictive association between human attitudes and environments and health-illness behaviors, morbidiby and mortality, as well as to develop methods of curtailing behaviors that are deleterious to health and of strengthening behaviors that promote health.

The influence of uncertainty on behavior

In the more tranquil economic and social world of the 1950s and 60s, it may have been possible to model behavioral responses effectively without worrying too much about the way in which uncertainty about the future influenced behavior. The assumption that the future is continous with the past, while never entirely satisfactory as a basis for modeling behavior, can reasonably be judged to have been more satisfactory then than it is now. Particularly:

(A) We need to understand how people form their judgments about the future—what information they use, what weights they give to various types of information, etc.;

(B) We need to understand how people cope with uncertainty, which can be defined operationally as a distribution of possible outcomes with a great deal of dispersion; and

(C) We need to understand the way in which decision outcomes, and possibly decision processes as well, are modified by the existence of a less stable economic and social environment.

A research agenda in this area clearly includes paying significant attention both to the development of analytical models designed to recognize explicitly the importance of uncertainty, and the generation of behavioral information from which we can begin to understand how decision-makers react to unstable external environments.

CONCLUSIONS AND RECOMMENDATIONS

These and other social science research topics have a common theme. They suggest that over the next decade the society can achieve major strides in understanding economic and social processes provided it is willing to make the right kinds of investment for a long enough period of time to produce tested and cumulative knowledge. The programmatic areas that I have described are all characterized by the need to pay attention both to the development of theory and method as well as the development of appropriate data-bases. And all of these programs require resources that are large relative to the current levels of funding for social science research within the NSF; they also require stability and continuity of support. If I am right that research programs such as the ones I have described represent areas in which substantial progress can be made, and that a large flow of societal benefits will result, the implication is that future levels of support for the social science research programs within the NSF will have to be substantially larger than they have been during past years.

At present the U.S. is at the cutting edge of research in the social sciences, largely because we have invested substantially more than other countries in the past. But as we know from familiar experience in other areas, that advantage can erode quickly. To prevent that error, I urge this Subcommittee to recommend an authorization for the NSF that restores the Social, Economic and Behavioral Science Programs to their fiscal year 1980 funding level.

I wish to thank the Subcommittee for inviting me to testify on this important issue.

American Chemical Society,
Washington, D.C., May 12, 1982.

Hon. Bob Packwood,
Chairman, Committee on Commerce, Science and Transportation,
Washington, D.C.

Dear Mr. Chairman: The American Chemical Society is pleased to have this opportunity to present its views on the National Science Foundation. The Foundation's importance to the scientific research enterprise in the U.S. is beyond dispute. NSF bears the major responsibility for maintaining the health of basic scientific research in the U.S. It accounts for about 28 percent of federal support for basic research in academic institutions and maintains U.S. scientific strength by funding research in all fields of science and engineering, through grants to more than 2,000 colleges, universities, and other research institutions in all parts of the U.S.

The statement presented in the following pages focuses on research and education in chemistry because this is the area in which we have the most information. However, these remarks are not to be interpreted as a plea for chemistry alone, since history shows quite clearly that an orderly development of the entire fabric of science is essential for the health of any single science.

ACCOMPLISHMENT AND POTENTIAL IN CHEMISTRY

Contributions made by chemistry to our national progress are most impressive. New and better materials ranging from the super-tough fiber "Kevlar" to medicinals such as the newly approved Hepatitis B vaccine, and the platinum complex for treating one of the forms of cancer, and to a variety of agricultural chemicals which are essential to our agricultural enterprise have their roots in the science of chemistry. Technology arising directly from chemistry is responsible for 6% of our gross national product. In addition, chemistry plays a supporting role in food production and a crucial role in energy technology. These two areas account for over 30% of the gross national product.

Basic research in photochemistry, physical chemistry, and solid state inorganic chemistry contributed to the development of the silicon integrated circuit. The advent of ultra-clear glass made possible the development of optical fibers which are bringing about dramatic changes in the communications industry. The discovery of a catalytic method for refining petroleum, and its inclusion in the crude oil refining process through imaginative chemical engineering, increased the gasoline yield from crude petroleum to 80% as compared to a value of 50% without the process. It is estimated that 200 million barrels of crude oil are saved each year by this process. Finally, chemistry is important to most scientific disciplines ranging from molecular biology to astronomy. Chemistry is truly a "central science."

The potential opportunities for further discovery and development in the chemical sciences are vast. Chemistry is poised as never before to enter a new period of fruitful inquiry because of advances in theory, discoveries in synthetic chemistry, and the advent of new classes of instrumentation. Whether or not the U.S. develops this potential depends on the resources which we as a nation are willing to commit.

SOURCES OF SUPPORT FOR BASIC CHEMICAL RESEARCH

According to the NSF series Federal Funds for Research and Development, total federal funding of basic chemical research was $290 million in 1981. Six federal agencies are the major sources of funds for such research in chemistry: the National Science Foundation, the Department of Energy, the Department of Defense, the Department of Agriculture, the Environmental Protection Agency, and the National Institutes of Health. In 1981 the NSF provided about 10% of the federal support for basic research in chemistry in the U.S. On the other hand it funded 33% of all university basic research in chemistry. Thus the vitality of the research base in our academic institutions depends heavily upon NSF.

Support of NSF is probably one of the better long-tern uses of federal resources. The Foundation's support of chemical research is crucial to the advancement of chemistry on all fronts because NSF tries to ensure the pursuit of opportunities in basic research not explored by the mission agencies. NSF can support th "bold idea" or "new thought" from which the next major scientific advance will come.

According to NSF statistics, support for basic chemical research in the 1970's from all sources, federal and nonfederal, varied little in constant dollars. The federal share fluctuated around 40% while industry's share fluctuated around 50%; this latter point deserves comment. Industrial research complements, but is certainly no substitute for, federal efforts to advance the science of chemistry on all fronts. The programs of NSF provide the "cutting edge" of our research enterprise. Their importance is far larger than their dollar value would indicate.

NSF REQUEST FOR FISCAL YEAR 1983

It is in the best interest of the country for Congress to fund the NSF at the level proposed by the Administration for FY 1983. Under this proposal, support for research and related activities would increase from the fiscal year 1982 current plan of $969.7 million to a total of $1,055.6 million in fiscal year 1983, representing an increase of $84.9 million or 8.7 percent. In view of the urgent need to reduce the federal budget deficit and the resulting intense pressure to cut discretionary programs, the Society supports the Administration's budget. However, the proposed funding level for NSF is by no means the optimum. Many excellent research proposals deserving support will continue to be unfunded, as was the case in the past years in the Chemistry Division at NSF.

The fiscal year 1983 proposed budget for the Chemistry Division is $66.1 million. This represents an increase of $5.4 million or 8.9 percent, allowing for little growth when discounted for inflation. Following upon six consecutive no-growth years, the request for fiscal year 1983 clearly is not extravagant. The same can be said about the proposed funding for the Chemical and Process Engineering Division, and for other NSF programs in which chemistry plays a supporting role. The U.S. cannot afford the luxury of funding less research through NSF than proposed by the Administration.

NSF PROGRAMS SUPPORTING CHEMISTRY AND CHEMICAL ENGINEERING

[Dollar amounts in millions]

	Fiscal year		Percent increase
	1982	1983	
Chemistry	$60.7	$66.1	8.9
Chemical and process engineering	20.1	22.2	10.4
Other Programs:			
Materials Research:			
Solid State Chemistry	6.0	6.85	14.0
Polymers	5.3	6.0	12.6
Materials Labs	22.5	24.2	7.5
Biochemistry	10.5	11.1	5.7
Atmospheric chemistry	6.9	7.9	14.3
Geochemistry	6.8	8.7	27.9
Marine chemistry	10.4	11.1	6.7

MANAGEMENT OF THE NATIONAL SCIENCE FOUNDATION

The American Chemical Society has full confidence in the National Science Board and in the current management of the NSF. We reiterate a statement made on April 27, 1981 by Professor Albert Zettlemoyer, 1981 President of the ACS, before the Subcommittee on Science, Technology, and Space of the Senate Committee on Commerce, Science, and Transportation. He said, "We urge the Congress to exercise its oversight functions and continue to review, analyze, criticize, and support the Foundation, while resisting the natural inclination to become too explicit in instructing the Foundation on how to achieve its mission."

In our judgement the NSF is very effective in supporting only top quality science. Seven specially-appointed panels of distinguished scientists reviewed the operation of the Chemistry Division in 1980. Without exception these seven panels of experts praised the methods used by the Chemistry Division to ensure that only high quality research is funded. The programs reviewed represented research of very high quality.

We will not turn to the consideration of a number of issues facing the U.S. chemical profession.

INSTRUMENTATION

An expanding body of information indicates that the instrumentation used to train students in our universities is clearly inferior to that used in industry. Advances in instrumentation have been occurring at a furious pace, principally because of advances in electronic hardware and computers. Replacing worn-out instruments and laboratory equipment, and updating laboratories with new, advanced instrumentation, are extremely expensive propositions. Most academic laboratories have not been able to keep up. The end cost can be enormous because research laboratories that are inadequately equipped spawn inefficiencies and produce inadequately trained scientists. The obsolescence of instrumentation used for instruction is even worse than that for research instrumentation.

The present plan of the NSF Chemistry Division to put $5.8 million into instrumentation for departmental use and an additional $6.0 million for special instrumentation for individual research projects is extremely wise. This plan recognizes the dependence of the research enterprise on an expanding arsenal of very sophisticated research tools. These new instruments are urgently needed for both research and training. However, it must be recognized that this $11.8 million is being diverted from research grants. This approach is not the ultimate answer to the instrumentation problem. The funds obtained in this manner do not measure up to the magnitude of the problem.

ADEQUACY OF RESEARCH GRANTS IN CHEMISTRY

There is evidence that the current limited research budgets are seriously hampering desired scientific advances. The seven outside panels that reviewed the way the Chemistry Division dispenses its grant money were dismayed at the large number of good research proposals that had to be declined for lack of money. The extremely competitive nature of the selection process severely affects the young investigators who are tomorrow's professors. The NSF Chemistry Division is currently funding only one out of five proposals received from first-time applicants. Those who are new to the system and have not developed a long record of accomplishment are having a terrible time obtaining funding. In some cases their inability to obtain funding has been used to deny them permanent positions on university faculties. It is quite certain that more than 20 percent of the bright young men and women beginning careers in university teaching are capable of doing constructive and valuable research. The American Chemical Society believes that when so many young investigators cannot get funding, our country is the loser.

Because inflation is very seriously eroding the ability of investigators to carry out their research goals, the Chemistry Division has decided to increase the average size of grants in fiscal year 1983 to compensate for inflation. Most of the budgeting increases for chemistry will be used in this manner and the overall number of grants will remain constant at 875. Thus, the long-term problem of an insufficient number of grants will remain.

In Chemical and Process Engineering the fiscal year 1983 budget provides for an increase in the number of awards. In spite of this increase, the overall number of awards in fiscal year 1983 remains relatively small at 403.

SCIENCE EDUCATION

Science education is one of the more visible trouble spots in the U.S. scientific apparatus. A host of problems have been identified and much information is already on the record. The major issues are reviewed here.

Proficiency of high school graduates in mathematics and science

The problem of scientific literacy for our citizenry looms as a challenge to all of our hopes and dreams as a nation. For reasons still not well defined, the interest of young Americans in science and mathematics is declining. The situation has been worsening over the past 15 years. The presentation of science to our young people in high school and college is generating little interest in this area of human endeavor that is truly central to life in any modern nation. Fewer and fewer high school students are taking courses in high school chemistry, physics, or mathematics. In 1980 less than 17 percent of the students in high school had studied chemistry and only 10 percent had studied physics. This problem is at the root of the shortage of technical experts in America. In view of the demographic data indicating that the number of U.S. citizens reaching the age of 18 will decline over the next 10 years (from 4.2 million in 1980 to 3.3 million in 1990), there is cause for concern that the pool of talent required to operate America's industrial and military enterprise is shrinking at a time when opportunities for discovery and development are very high. This problem deserves serious examination by academia, industry, and government.

Shortage of qualified science and mathematics teachers

Fewer young people are preparing to become science and mathematics teachers, causing a severe shortage in these fields. According to the National Science Teachers Association, a recent survey of secondary school principals shows that 50 percent of the newly employed science and mathematics teachers are unqualified. They are employed on an emergency basis because of the shortage of qualified teachers. In addition, it has been brought to the attention of the Society that teachers experienced in other fields but without credentials for chemistry teaching are being reassigned by school administrators to the chemistry classroom.

Ph. D. supply in chemistry

At present there is a serious concern about whether the U.S. will have an adequate number of chemical professionals to operate the chemical enterprise in the next five years. A severe shortage of Ph. D. analytical chemists already became apparent last year. This problem is so severe that a chemical industry panel is investigating the options faced by the chemical profession. The shortage of chemical engineers is also recognized as a serious national problem. Survey data indicate that the situation will get worse before it gets better.

A major portion of the chemical research and development work of the country is spearheaded by well trained Ph. D's. Thus, the supply of chemistry Ph. D.'s concerns us. In 1980 the country produced fewer Ph. D's in chemistry (1,538) than in 1966 (1,594). To put this comparision into perspective, the number produced in 1966 was judged to be inadequate to meet the nation's needs then. A further complication is that 22 percent of the Ph. D.'s produced in 1980 was composed of foreign nationals, many of whom are not available for the U.S. labor force.

Strategy in science education

Last year the American Chemical Society strongly opposed the elimination of funds for Science and Engineering Education at the NSF. We stated this position to the Administration and to the Congress. The Society has a very genuine interest in science education. A number of ACS permanent operations are devoted to chemical education, including a staff of 30 at National Headquarters, a Committee on Chemical Education, and a Division of Chemical Education with 2,800 members. These activities are a major component of the total ACS operations. Thus, as one might expect, the Society supports a strong federal effort in science education.

This year, again, we are facing an NSF budget that eliminates the Directorate of Science and Engineering Education and takes the Foundation out of the education business, except for the continued administration of a graduate fellowship program of $15 million. The National Science Board and the Director of NSF are looking to the new Commission on Precollege Education in Mathematics, Science, and Technology to come up with a plan to "do something about the problems" in precollege mathematics and science education, and not just to study them.

This course of action has been seriously questioned by members of the Congress and by organizations concerned about the state of science education in the U.S. While remaining strong supporters of a federal role in science education through the NSF, the Society does support the concept of the Commission. The following points carried great persuasive weight in the formulation of our position:

As stated earlier, the problem in science education developed over the past 15 years. It took the convergence of many actions and factors to bring about the current scientific illiteracy that is a national disgrace. Factors beyond the control of any one group were at work, such as the cultural aversion to science and technology that developed in the 60's. Research scientists are to blame for their neglect, and sometimes disdain, toward science educators. Educators are to blame for some poorly thought out programs which did not deliver as expected. Government programs demanding that scientists choose between careers in research or education are to blame. And finally, the Congress is to blame for creating a hodgepodge of programs in response to the desires of its members' constituencies.

The Administration is proposing the termination in FY 1983 of all NSF activities in science and engineering education, except for the graduate fellowships program. It is clear that the decision was precipitated in part by budget constraints. The termination of all NSF involvement in precollege education in science and mathematics would be totally unacceptable. Such action would violate the statutory charter of the Foundation, and is not responsive to current national needs. We take note, however, that the National Science Board and the Director have taken steps that could pave the way toward a fresh start for the Foundation in the realm of precollege education in science and mathematics.

The Society looks upon this approach as an opportunity for the science and education community to pull together and develop a consensus on how to achieve science literacy in the public. The Society also hopes that the Commission will be a mechanism for highlighting this national problem. This visibility may instill in the public a sense of the magnitude of the problem and the need to devote to it public resources at all levels of government—federal, state, and local—as well as private efforts within the community and the family structure.

For the reasons stated above, the ACS supports the work of the Commission. The Society also endorses the Foundation's current plan to continue funding graduate fellowships. These have been extremely effective in training future scientists. In addition, the Society would strongly endorse the creation of a reserve, perhaps $10 million, to be used to implement sound recommendations for improving science education that may emerge from the early stages of the work of the new Commission, the NSF and the National Science Board. In making this recommendation, we emphasize that such a reserve should not be created through diversion of funds from the research activities of the Foundation.

SUMMARY

The ACS urges the Congress to fund the NSF at the level requested by the Administration for fiscal year 1983.

The Society endorses the effort of the National Science Board's Commission on Precollege Education in Mathematics, Science, and Technology.

The American Chemical Society appreciates this opportunity to submit its views on the National Science Foundation and the state of the chemical research enterprise. ACS is an individual membership organization of more than 120,000 chemists and chemical engineers reflecting a broad spectrum of academic, governmental and industrial professional pursuits. Founded in 1876, the Society was granted a National Charter in 1937 by an Act of Congress. The objectives stated in the ACS congressional charter are to encourage the advancement of chemistry and to promote research in chemical science and industry, thereby fostering the public welfare and aiding in the development of our country's industries. The Society stands ready to assist this Committee in any way which you deem appropriate in carrying out the important charge before you.

Sincerely,

ROBERT W. PARRY,
President.

[From the Albuquerque Journal, Apr. 4, 1982]

TWO HOPE TO TABULATE N.M. MINES

JOURNAL SPECIAL

SOCORRO.—In a national emergency, the United States would be vulnerable not only to oil embargoes, but also to a cutoff of many other strategic resources.

A variety of minerals important to American industry and security come from nations whose governments range from unstable to openly hostile. Chromium and manganese, for example, are produced largely in South Africa and the Soviet Union.

One solution is to know the location and extent of all such mineral reserves. A thorough study would benefit geology and mining in general as well as helping bolster national security, state mining officials claim.

A long-time answer is CRIB, the Computerized Resources Information Bank. Its ultimate goal is the tabulation of as many mines and prospects as possible all over the world.

Mining engineer Robert Eveleth and geologist David Menzie of the New Mexico Bureau of Mines and Mineral Resources would be satisfied with getting New Mexico's mines on file in the computer. The state's contribution to the mining industry has been formidable.

"I would conservatively say there are 10,000 or more mines and prospects, and we have good, solid information on about 2,500," said Eveleth.

It doesn't matter how old or how new the mine is or what, if anything, it ever produced. Information on any mining activity in the state goes into Eveleth's and Menzie's files in this U.S. Geological Survey-funded project.

Sources of such information are generally those popularly associated with geology, but not always. If Eveleth and Menzie find themselves searching a dim and dusty passage, it's just as likely to be in a library as in a mine. To learn about old mines, they pore over literature, manuscripts, records and photographs: "Age makes no difference," says Eveleth.

While Eveleth and Menzie are concentrating on New Mexico's mines, the records are where they find them. Fortunately, some mining engineers and geologists of days gone by kept copious journals; one, said Eveleth, left his heirs no less than seven tons of aging paper. The bureau archives are seeking private donations of anything related to mining, geology, or railroading.

As might be expected, the mining companies themselves left—and in some cases are still leaving—some of the best clues. A yellowing prospectus or a faded annual report is treated by the two researchers like a treasure map in their offices at the

New Mexico Institute of Mining and Technology. New information is equally valuabel and eagerly sought.

Their work updates and builds on a foundation laid in the early 70s by the U.S. Geological Survey. When the data have been assembled and processed, they will become available to a broad spectrum of users.